MEDICAL DEPARTMENT
UNITED STATES ARMY
IN WORLD WAR II

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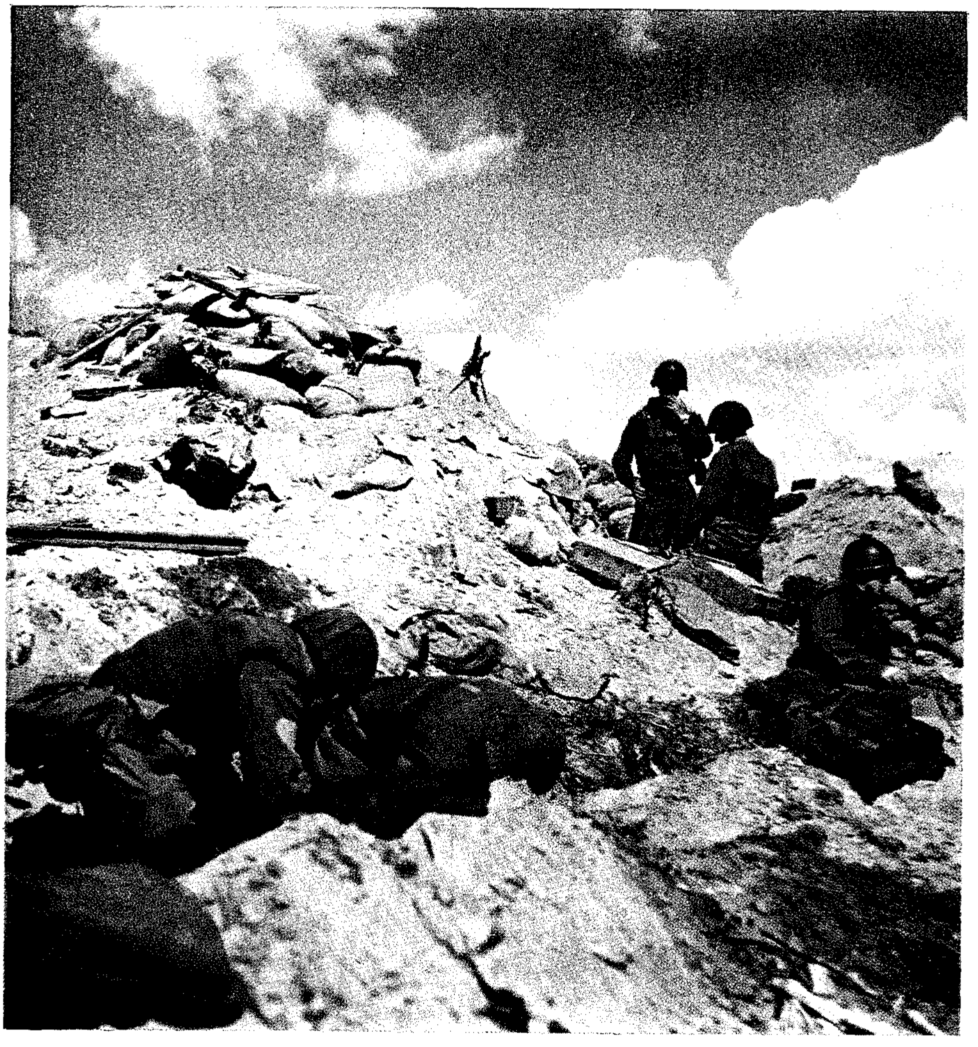

Body Armor in Korea

MEDICAL DEPARTMENT, UNITED STATES ARMY

WOUND BALLISTICS

Prepared and published under the direction of
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WOUND BALLISTICS IN WORLD WAR II

Supplemented by Experiences in the Korean War

The Historical Unit, United States Army Medical Service

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Foreword

War, which has been a bane to man since his earliest days, has always been characterized by the presence of those who attempt to devise more and more effective ways to maim and destroy the enemy, of others who strive to develop the means to protect their comrades from the implements of the foe, and of still others on both sides who devote themselves to improving techniques for the care and repair of the unfortunates who are the casualties of war. These three facets of war are interdependent, and one group cannot achieve the best results without the advice and assistance of the others. The thread which binds and correlates their activities is the science and application of the principles of wound ballistics.

Field Service Regulations, 100–5, Operations, provides that coordinated action of all arms and services is essential to success. It is to such coordinated action that accomplishments within the U.S. Army in the field of wound ballistics owe their success. This volume relates the part played by the Army Medical Service in this mutual endeavor during World War II and, in briefer fashion, during the Korean War.

In the development of personnel armor, the approach of the Army Medical Service is very similar to its approach to a disease entity. Primarily, the Army Medical Service is interested in the treatment and recovery of the casualty and in his speedy return to the fighting force. It is also interested in and vitally concerned with any methods which can reduce the severity of the wound or any devices which can bring about complete defeat of a wounding agent. When, as in Korea, the mortality rate of the wounded reaching medical treatment facilities was reduced to approximately 2.3 percent, these secondary interests loom large. Capitalizing on the experiences of World War II and the early experiences of the Korean War, the Army in 1951–52 introduced body armor with most significant results. There was a decrease in the number of wounded and the killed in action. There was a decrease in the severity of wounds, which in turn resulted in more rapid and early convalescence and, because of the lightened workload, permitted surgical units to provide better care to those requiring it. While these results were gratifying, they most definitely indicated the need for continuing research and development to provide adequate ballistic protection for the head and those regions of the body which received the largest number of lethal wounds.

The message which this volume contains for the physician who will be treating the wounds of war is clear. War wounds, in many respects, are different from those found in peacetime civilian practice. Unless the physician has some knowledge of the weapons and missiles which are creating the wounds and of the wound track characteristic of these causative agents, his clinical

decision as to the treatment necessary is perforce shortsighted, and unwarranted errors may result. Examples of errors of this type are fully discussed in this and other volumes of the World War II history of the Medical Department, but the basic data contained in this volume, if they are studied and the lessons learned, should go a long way in dispelling the ignorance which leads to such errors.

Finally, the Army Medical Service expresses its deepest gratitude to the contributors to this volume and to all individuals, both civilian and military, whose zeal and patriotism made possible, often under trying circumstances and without precedent, the collection and preparation of the original data upon which this work is based. My appreciation is extended to Maj. James C. Beyer, MC, for so admirably accomplishing the arduous and major task of compiling and editing this volume. His keen interest in this special field of military medicine and his exemplary work and experience in Korea and at the Armed Forces Institute of Pathology, Washington, D.C., made him the ideal individual to undertake this project.

LEONARD D. HEATON,
Lieutenant General,
The Surgeon General.

Preface

Medical interest in the battle casualty as to the type and anatomic location of his wounds, the correlated visceral damage, and the causative missiles has been in evidence since the earliest days of organized combat. The founding of the Army Medical Museum during the Civil War and the resultant collection of case histories, drawings, anatomic specimens, and recovered missiles was a major milestone in the accurate documentation of wartime medical history. Notwithstanding its seeming antiquity in the light of present-day standards, the collection is of unique and unparalleled value, and its complete exploitation has never been fully realized. Near the close of the 19th century, Col. Louis A. La Garde of the U.S. Army Medical Corps, in conjunction with the Ordnance Department, conducted numerous experiments in basic wound ballistics and later extended his observations to the casualties of the Spanish-American War.

During World War I, there were numerous small casualty surveys conducted by medical personnel of great vision and foresight, but there were no formal directives governing such activities. Col. Louis B. Wilson of the U.S. Army Medical Reserve Corps made a rather extensive study of the wounds in casualties of World War I, and this, coupled with his interest in the subject of ballistics, enabled him to reach a number of basic conclusions regarding the wounding effect of a bullet. In later years, Colonel Wilson was active in directing the ballistic research of Col. (later Brig. Gen.) George R. Callender, MC, and M. Sgt. (later Major, SnC) Ralph W. French. Much of this work was an attempt to carry out on a scientific basis experiments which would prove, disprove, or modify statements Colonel Wilson had made regarding the wounding potentials of small arms missiles.

Unfortunately, the excellent collection of pathologic specimens by the British Army Medical Service from World War I was partially destroyed during the bombing of London in World War II. This collection at the Royal College of Surgeons resulted from the activity of the British Medical History Committee which from its origin had a duty "to collect examples of the wounds and diseases suffered by soldiers in the present war [World War I]; to dissect and examine such specimens in order to fully understand their extent and nature so that the best means for their treatment might be adopted; and to preserve instructive examples so that they might be examined and studied not only by Army surgeons of today but also by medical men for many generations to come." According to Sir Alfred Keogh, Director-General of the Army Medical Service (20 Oct. 1917): "Such specimens are original documents, they constitute an original and reliable source of knowledge for all time, and supply the most valuable basis possible for present and future medical and

surgical treatment of the diseases and injuries of war." Such sentiments are still applicable in the elucidation of the value and function of a battle casualty survey unit. The collected information and specimens can be channeled into various fields for instruction, training, and developmental purposes, both within the medical service and within the other technical services, and for permanent display and historical storage.

In addition to determining the location and types of wounds in battle casualties, it is also essential that the members of a survey team be familiar with enemy ordnance materiel. One must learn to recognize the characteristics of the external wound and the permanent wound track and, in addition, attempt an identification of the causative missile, of its approximate mass, and of its striking velocity. In small arms missiles, it is desirable to be aware of the effective rate of fire and range of the weapon and the types and makeup of the ammunition. With fragment-producing weapons, it is essential to determine the types of shells and the mass distribution and initial velocity of the fragments. By means of such information, a more adequate and intelligent analysis can be made of wounds and their causative agents, and valuable data can be made available for dissemination to other technical services for weapons' evaluation and development of personnel armor. This leads to an excellent liaison and interchange of ideas, test results, interpretations, and guidance between the interested technical services.

Chapter I of this volume deals with the enemy ordnance materiel of World War II and Korea insofar as it had a bearing on casualty surveys. An attempt was made to make it as informative and readable as possible while still maintaining the security of information classified in the interest of national defense. Maj. James K. Arima, MSC, and Mrs. Doris Johnson (nee Walther) of The Historical Unit, U.S. Army Medical Service, were responsible for the collection and compilation of much of the information, and this was possible only after a review of a large number of publications, principally ordnance, and correlating the various weapon specifications which in many cases had a great variability. In addition, members of the various sections of the Ordnance Technical Intelligence Service, U.S. Army, were very helpful in reviewing the material for accuracy and security. The wholehearted cooperation of various members of the Ordnance Department in compiling the material and in its final review for publication has been most encouraging.

During the interim between World Wars I and II, active research on a probable mechanism of wound production by high-velocity missiles was conducted by General Callender. Most of this pioneer work was done in collaboration with Major French. In chapter II, they have utilized some of their original material to elaborate upon the correlation between a missile, its mass and velocity, and its wounding potential. Both authors are to be commended for the quality and originality of their research and for the particular correlation which has existed between their laboratory experiments and later fieldwork.

In September 1943, Mr. R. H. Kent, physicist at the Aberdeen Proving Ground, Md., contacted Dr. Lewis H. Weed, chairman of the Division of

Medical Sciences of the National Research Council, regarding the establishment of a research project designed to test the casualty-producing effectiveness of U.S. weapons. As a result of this request, a meeting of the newly created Conference on Wound Ballistics, later called the Conference on Missile Casualties, was held on 25 September 1943. General Callender presided and Dr. John F. Fulton was secretary of the meeting. After accepting the general tenets of Mr. Kent's proposal, the Conference granted contracts for research projects to several groups of investigators. One of these contracts led to the monumental work reported by E. Newton Harvey, Ph. D., and his associates (chapter III). Much of this material has been published in separate medical journal articles, but this volume would be grossly deficient if it were not present. Many of the original conclusions of this work have been the basis for continuing ballistic research after World War II. Floyd A. Odell, Ph. D., Technical Director of Research, U.S. Army Medical Research Laboratory, Fort Knox, Ky., and formerly of the Biophysics Division, Medical Laboratories, Army Chemical Center, Md., kindly furnished a copy of the original manuscript and a complete set of negatives for illustrations. The excellence of the illustrations in chapter III is due solely to the availability of these negatives.

The natural extension of basic wound ballistic laboratory research into field surveys and the increasing awareness of the need for data on battle wounds was recognized by the Conference on Missile Casualties, and in early October 1943, a general recommendation was made that special teams be appointed to conduct battle casualty surveys and that some attention be given to the training of personnel qualified to conduct these field activities. On 14 October 1943, the Conference prepared a formal proposal directed to The Surgeon General of the Army concerning the formation of a special survey unit which could receive its initial indoctrination in the United States and its subsequent training with Prof. Solly Zuckerman's group at Princes Risborough in England. It was felt that such a team should consist of approximately six to eight persons, including medical personnel qualified in pathology and surgery and other technical service personnel having training in physics, interior and exterior ballistics, and other ordnance specialties.

Subsequent to this proposal, General Callender informed the Conference on 5 November 1943 that The Surgeon General and Brig. Gen. Fred W. Rankin, Director, Surgical Consultants Division, were in agreement concerning the need for data on wounds in battle casualties but felt that the immediate shortage of trained men precluded the appointment of any special team. Instead, it was recommended that theater commanders be advised of the need for the information and that they then assign medical officers under their command to collect wound ballistic data for transmittal to the Conference on Missile Casualties. General Callender prepared an article in which he described the startling lack of available information and outlined the overall scope and organization of a casualty team and the type of data which was needed. This article was published in the March 1944 issue of the *Bulletin of the U.S. Army Medical*

Department. Before general publication, copies of the article were sent to all theaters of operations.

As a result of General Callender's article, a survey team was organized under Col. Ashley W. Oughterson, MC, to cover a phase of the Bougainville Island campaign from February to April 1944. Because of his tragic and untimely death near Cali, Colombia, in November 1956, Dr. Oughterson was never able to review the revision of his original report as it was prepared for chapter V of this volume. However, this manuscript was recovered through the gracious cooperation of his widow, the late Dr. Marion E. Howard, and was reviewed by another member of the original survey team, Dr. (then Colonel, MC) Harry C. Hull. The Bougainville survey team performed an outstanding and pioneer effort, and their organization and report served as the basis for the development and efforts of later casualty survey units. It is most regrettable that the death of Dr. Oughterson prevented him from seeing his report reach the final publication and public recognition which it so justly deserves.

Even before the dissemination of the directive prepared by General Callender, another young Army Medical Corps officer was actively engaged in the study of battle casualties. This officer was Capt. James E. T. Hopkins, MC, whose work in the New Georgia and Burma campaigns is reported in chapter IV. Because of his own innate interest and ambition, Captain Hopkins undertook a study of casualties in the New Georgia campaign for the period, July to August 1943. Following this, he was stationed in Burma and studied casualties there in the period, February through May 1944. Both of these surveys have produced unusual and valuable information regarding the type of casualty and causative agent in jungle warfare. Since case reports from this survey are unique in that they describe the battlefield duty and anatomic position of the soldier at the time he was wounded, they have been included in their entirety in appendixes A, B, and C. Some of the conclusions which were reached by the author regarding the training of infantrymen and their use and conduct in the field were highly pertinent and valuable at the time the original material was prepared and would undoubtedly prove of equal importance in the event of similar jungle-type warfare.

Simultaneous with the conduct of casualty surveys in the various areas in and about the Pacific, additional survey teams were being organized in Europe. Brig. Gen. (later Maj. Gen.) Joseph I. Martin, Surgeon, Fifth U.S. Army, Mediterranean theater, arranged for and obtained authority to study the killed in action, and Capt. (later Lt. Col.) William W. Tribby, MC, was assigned to this duty.

Captain Tribby worked in association with Quartermaster graves registration units at U.S. military cemeteries in Italy and studied a thousand Americans killed in action in the Fifth U.S. Army from April to November 1944. This survey probably represents the largest single study of killed-in-action casualties conducted during World War II, and its scope was not surpassed until the Korean War. The survey was concerned primarily with the accurate anatomic location of wounds, their probable causative agents, and the cause of

death. The original report contains an outline figure of the body for each case with exact location and extent of all wounds. Limitations of space precluded the inclusion of these anatomic drawings in chapter VI of this volume, but the original work is still available as an invaluable reference.

In addition to the survey of Fifth U.S. Army killed in action, another survey was conducted by Col. Howard E. Snyder, MC, and Capt. James W. Culbertson, MC, on battle casualty deaths in hospitals of the Fifth U.S. Army (chapter VII). A statistical analysis was made of case reports from field and evacuation hospitals on 1,450 fatally wounded American soldiers during the period from April through September 1945. Only a small fraction of the original material is contained in the present chapter. The authors concerned themselves not only with the anatomic location of wounds, the probable causative agent, and cause of death of the casualties but thoroughly investigated all the possible surgical avenues which might have had a bearing upon the fatal outcome of the soldier. Therefore, they investigated a wide variety of subjects ranging from time lapse between wounding and entrance into a medical facility and early surgery, possible effect of anesthesia, use of blood transfusions, and a wide variety of other topics all of which are immensely important to the military surgeon of any war.

Next, there are three chapters (VIII, IX, and X) and appendixes G and H all prepared and written by Maj. (later Lt. Col.) Allan Palmer, MC. Perhaps no other author in this volume has waited so long and so patiently for the publication of his works. Nevertheless, he was still able to maintain a wholesome interest in his original work and a genuine desire to cooperate in its final review. In April 1943, Major Palmer became associated with Professor Zuckerman for the purpose of studying field casualty survey methods. The first survey conducted by Major Palmer was with the Fifth U.S. Army during the Rapido River conflict south of Cassino in January 1944 (chapter VIII). Notwithstanding the small number of casualties in the survey, it still serves as a model for future field casualty survey studies. In addition, certain valuable information can be gathered concerning the type of casualties to be expected under certain specific forms of ground combat.

Major Palmer's major effort was concerned with a survey of all Eighth Air Force heavy bomber battle casualties returning to the United Kingdom during June, July, and August 1944. At this time, Major Palmer was chief of the Medical Operational Research Section, Office of the Chief Surgeon, European Theater of Operations, U.S. Army. The section had been organized under the direction of Maj. Gen. Paul R. Hawley, Chief Surgeon, and Col. (later Brig. Gen.) Elliott C. Cutler, MC. In addition to making a study of casualties (chapter IX), an exhaustive survey was made of the effects of flak striking aircraft and their correlation with the associated casualties among crew members (chapter X). Appendix G relates the accidental discharge of an aerial bomb at an airfield in England. Again, this survey can serve as a model for future studies of accidental discharges of weapons during wartime or during training procedures. Unfortunate as these accidents are, they can still serve as

a source of some valuable information concerning the potential and possible lethal effects of our own weapons.

After the work with the Eighth Air Force, the Medical Operational Research Section was reconstituted as a survey unit and moved into the Third U.S. Army area on the European Continent. The unit finally became fully operational just 2 days before V–E Day. Major Palmer prepared a very interesting and informative diary of the experience of this unit from the time it left England until the cessation of the war. It is of great interest for anyone who has been associated with a field casualty survey unit to read the diary and see the many pitfalls and complications which developed in the unit's attempt to become operational.

Owing to his field experience, Major Palmer was able to study the various casualty surveys from World War II and to correlate all the surveys in regard to anatomic location of wounds and to the possible causative agent (appendix H). Even though there is a mixture of casualty surveys conducted under different collecting criteria and composed of aircrew and ground force casualties, many interesting correlations can be obtained.

Despite the fact that this volume was originally intended to include only the work of World War II, the casualty surveys and subsequent development of personnel armor during the Korean War was such a natural outgrowth of the World War II experience that the Korean material could logically be included in this volume. Numerous investigators during World War II had advocated the development and use of some form of body armor for ground troops. Through the untiring efforts of Brig. Gen. Malcolm C. Grow of the U.S. Army Air Forces, personnel armor was provided for members of bomber crews and was of undenied success in reducing the number of overall wounds and the number of lethal wounds. Numerous prototypes had been developed for ground forces, and a test model was ready for field testing at the time of the conclusion of the war with Japan. Therefore, it would seem that body armor should have been a standard item of equipment at the onset of the Korean War. However, it was tragic to see the effect that peacetime had had on the thinking of those individuals who could have been responsible for the use of body armor at the immediate onset of the conflict. It was only due to the administrative ability and guidance of Col. (later Brig. Gen.) John R. Wood, MC, and several field surveys conducted under the leadership of Lt. Col. (later Col.) Robert H. Holmes, MC, that the responsible agencies would consent to the development of prototypes and the field testing of models. New statistics had to be compiled from field surveys, and old arguments had to be refought and won before any models were developed for field usage. Initially, Colonel Holmes laid the basic groundwork for the development and successful acceptance of personnel body armor for Army ground troops. Later, Lt. Col. (later Col.) William W. Cox, MC, and Maj. William F. Enos, MC, were instrumental in the final testing and standardization of the present all-nylon model. Numerous other medical officers as well as Quartermaster, Ordnance, and infantry officers

were also concerned with the gathering and interpretation of valuable field statistics.

It is perhaps a natural consequence of the American philosophy not to maintain a constant interest in certain military matters in peacetime. However, it is costly both from the usual sense of time and money lost and from the even more fundamental and irreplaceable point of view of human lives being lost when certain fundamental suggestions and conclusions reached in one war are completely lost in intervening times, and the points have to be regained in subsequent wars.

Chapter XI is concerned with the development of personnel armor for ground troops as seen as in World War II. The major portion of this chapter must of necessity be concerned with various forms of helmet design and protection which were developed in response to varying needs of specific forms of combat duties. Most of the source material for this chapter was obtained from the historical files of the Ordnance Department. It was only due to the unlimited cooperation of historians in the office of the Chief of Ordnance, in offering all the available materials in their files to the authors, that this chapter is possible. Major Enos was one of the medical officers on the survey teams testing one of the prototypes of the Army personnel armor in Korea, and despite his resignation from the service he has still maintained an active interest in the field and has always been available to the Office of the Surgeon General for invaluable consultation and advice.

Development of personnel armor in the Korean War was so intimately associated with and a direct consequence of casualty surveys conducted in that conflict that both aspects have been combined in chapter XII. There is also a natural association of authors in this chapter for Carl M. Herget, Ph. D., is perhaps the foremost leader in laboratory investigations on basic wound ballistics and testing of personnel armor and Capt. George B. Coe, Ordnance Corps, was one of the foremost leaders in Korean casualty surveys. Dr. Herget and his able associates in the Biophysics Division, Medical Laboratory, Army Chemical Center, were instrumental in directing many of the Korean casualty survey units, since laboratory experiments had disclosed fields in which knowledge was vitally needed, and conversely much of the information that could be gained by field units was of utmost value to laboratory workers in directing their own research programs and in interpretation of some of their results. Captain Coe, then 1st Lieutenant, Medical Service Corps, made numerous trips to Korea as a member or as a leader of missions conducted for the field testing of body armor and the gathering of information concerning various types of battle casualties. In addition to this immense amount of fieldwork, he was also vitally concerned with and instrumental in the development of various prototypes of Army body armor, and before his transfer from the Army Chemical Center he was a mainstay in the development and the testing of newer models.

Many of the contributors to this volume have been most patient in awaiting publication of their World War II battle casualty surveys or results of research

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in basic wound ballistics. Those whose work was done under the rigors and expediencies of combat conditions are to be commended for their devotion and zeal to the immediate treatment of the wounded soldier and, additionally, for their great desire to study the factors which were important in producing the casualty. Many of these contributors came into considerable conflict with their immediate superiors, who at the moment did not see the possible value or application of their investigations. Undismayed, they continued their vital studies while performing outstandingly their prescribed duties.

One of the most valuable lessons to be gathered from much of the reported work is the relative constancy of warfare up to the Korean War. Anatomic location of wounds, causative agents, ratio between the wounded and the killed in action have all remained relatively constant since the various studies originated during the Civil War. In addition, the importance of close liaison between the Army Medical Service and the other technical services is shown to be of utmost importance in the gathering and dissemination of fundamental information which can be utilized by all services in the greater fulfillment of their primary duty and in the development of future lines of endeavor. The editor is firmly convinced that there should be a small group of readily available and highly trained medical personnel who could be utilized for the conduct of battle casualty surveys or the investigation of peacetime training accidents on very short notice.

Because of the limited and technical nature of much of the original source material, the sole responsibility for the final preparation and interpretation of all the chapters is assumed by the editor.

A great many individuals other than the authors themselves were responsible for the final preparation and publication of this volume. Foremost among those who have patiently awaited its publication and have always been available for consultation and invaluable advice is General Callender. Col. Calvin H. Goddard, MC, was originally scheduled to be a coeditor, but his untimely death cut short an association which had always been most stimulating and enlightening to the present editor and had held great promise of future training and guidance for him. Colonel Goddard was one of those unique individuals who was most proficient and efficient in performing a number of varied tasks. Firstly, he was a medical officer, but he was also a noted historian and writer and a pioneer investigator and world-renowned authority on ballistics, small arms missiles, and weapon identification. His absence will be very evident in certain portions of this volume, but it was fortunate that the basic plan of the book had been formulated before his death. All the contributors have been most generous in consenting to review their material which, after a lapse of a number of years, must have seemed relatively foreign. Numerous members of various casualty surveys conducted during the Korean War have all been available for consultation and criticism of the manuscript.

A major vote of thanks must be tendered to Col. John Boyd Coates, Jr., MC, Director of The Historical Unit, USAMEDS, and to the members of the

various branches of that unit who were most cooperative and more than patient in waiting for the final delivery of the entire manuscript from the editor.

Special appreciation is tendered to Col. Charles A. Pendlyshok, MSC, former chief of the Special Projects Branch, for his never-failing interest in the progress of this volume; to Miss Elizabeth P. Mason, cartographic compilation aid in the Special Projects Branch, for her preparation of the maps; to Mrs. Josephine P. Kyle, former chief of the Research and Archives Branch, who, with her staff, provided much of the archival material and corroborated data obtained from other sources; and to members of the Medical Illustration Service, Armed Forces Institute of Pathology, who, under the direction of Mr. Herman Van Cott, chief of that service, prepared the excellent layouts for the illustrations and mounted them for printing.

Finally, the editor gratefully acknowledges the assistance of Miss Rebecca L. Duberstein, publications editor of the Editorial Branch, who performed the final publications editing and prepared the index for this volume.

JAMES C. BEYER,
Major, Medical Corps.

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CHAPTER I

Enemy Ordnance Materiel

Maj. James C. Beyer, MC, Maj. James K. Arima, MSC, and Doris W. Johnson

In conducting a casualty survey to get information for a study on wound ballistics, it is imperative that the members of a survey team be cognizant of the types and capabilities of enemy ordnance materiel. To facilitate the collection of such data and to recognize and evaluate the wounding potential of enemy missiles, the medical personnel of such a survey team should be familiar with enemy weapons and missile types and their ballistic properties. This information is necessary to evaluate completely external and internal wound characteristics and concomitant tissue and organ damage. If an ordnance officer is included as a member of the team, the collection and dissemination of pertinent information on enemy ordnance characteristics is greatly facilitated. Such information is vital to medical personnel both in making the study itself and in developing ballistic protective devices, such as helmets and body armor. During the preliminary research stages before the adoption of body armor in the Korean War, casualty surveys conducted under the guidance of the U.S. Army Medical Service and other technical services established the priority of body areas to receive protection, determined the most commonly encountered wounding agents, and fixed the criteria for minimum protection in terms of ballistic properties.

In addition to these medical applications, wound-ballistic studies can be of value to ordnance technical intelligence personnel in their evaluation of enemy weapons and to ordnance engineers in their design of new weapons. Conversely, any casualty survey conducted among enemy casualties can furnish vital information regarding the effectiveness of friendly small arms and artillery.

During World War II, casualty surveys conducted on Bougainville, New Georgia, and Burma correlated the missile casualty and his wounds with the type of causative agent. The Bougainville report (p. 289), especially, contained an excellent analysis of the Japanese weapons used in the Bougainville area. Unfortunately, none of the casualty surveys from the European and Mediterranean Theaters of Operations contained similar information for German weapons. Therefore, much of the following material had to be abstracted from various manuals and reports which contained excellent descriptions of

the external and internal details of the weapons and their mechanics of operation but often failed to consider their casualty-producing properties.

Before proceeding with the descriptions of enemy materiel, a definition of some of the technical vocabulary of the ordnance expert and the officer of the line is presented for the benefit of the reader who may be quite unfamiliar with these terms. This presentation will serve the double purpose of making the subsequent material easier to understand for the uninitiated reader, and it will define our use of the terms to the expert who may have for each many connotative shades of meanings.

Blowback operated.—The operating principle of a weapon which uses the force of gases expanding to the rear against the face of the bolt to furnish all energy necessary for the bolt to extract the expended cartridge and to reload and fire another. This type of weapon is said to fire from an open bolt because the bolt is held to rear when the weapon is cocked. The bolt loads and fires the cartridge when the trigger is pulled. Blowback-operated weapons are not positively locked at the moment of firing, but the bolt is held closed either by its own weight or its weight plus that of a heavy recoil spring or some other mechanical system, such as a trigger joint, until the bullet has left the bore and breech pressures have dropped.

Cyclic rate of fire.—The rate at which a weapon fires automatically, expressed in terms of shots per minute; synonymous with maximum rate when the period of measure is 1 minute.

Effective rate of fire.—The rate at which a weapon may be expected to fire accurately in actual use and with due consideration for the prevention of damage to the weapon by overheating resulting from an excessive rate of fire and the time required to reload the weapon.

Gas operated.—The operating principle of a weapon which uses the force of expanding gases passed through an opening in the barrel to a separate gas cylinder to operate the extracting, reloading, and cocking phases. The breech is locked at the time of firing, which may be semiautomatic or automatic. There may be gas ports in the cylinder to control the amount of gases entering it, and a piston encased in the cylinder operates the bolt. The rate of fire is, accordingly, controllable to some extent in weapons with adjustable gas ports.

Hollow charge.—A hollow, cone-shaped arrangement of the charge in shells designed to concentrate the explosive force in one direction; a shaped charge.

Hotchkiss machinegun.—A simple, air-cooled, gas-operated automatic machinegun developed by the Societé Anonyme des Anciens Etablissements, Hotchkiss et Cie., of France and England, from an original design by Capt. Baron Adolph von Odkolek, Austrian Army, in 1895. A port drilled through the barrel a few calibers from the muzzle communicated with a cylinder attached below the barrel and housing a piston. When the projectile passed the port, expanding gases entered the cylinder and forced the piston to the rear until the gases escaped through an exhaust port. The compressed mainspring, working directly on the gas piston, returned it to its original position. The

bolt, itself, was similar to that of an ordinary hand-operated rifle, only in this case, the operating rod (piston) connected to it did all the work. Ammunition was fed in metal strips. The Czech ZB 26 (Brno) was a modification and improvement of these principles. The Brno was widely copied by the Japanese, Germans, and British. In British terminology, the name appeared as Bren, and in German parlance, Brunn.

Lewis machinegun.—A light, air-cooled, gas-operated automatic machinegun developed by Col. Isaac N. Lewis, U.S. Army, in 1911, with the Automatic Arms Co., Buffalo, N.Y. The gun featured a pinion gear which articulated with the racked underside of the gas piston. A clock-type winding spring was mounted inside the pinion. The entire pinion and spring mechanism was mounted inside a casing on the pistol-grip, trigger-housing unit. The gas piston and bolt traveling to the rear extracted the spent cartridge, positioned a new cartridge, and wound the spring, which provided the energy for the loading and firing phases. Thus, the operating spring was located out of the way of reciprocating parts; it was easily accessible; changes in rate of fire could be made even while firing; and the separate housing kept it free of dirt, water, or other damaging elements. Because ammunition was fed from a 47- or 96-cartridge drum mounted flat on the gun, one man could operate the Lewis machinegun. Accordingly, it found great use in World War I and immediately thereafter as aircraft armament.

Maxim machinegun.—The first automatic machinegun was invented by an American, Hiram Maxim, in 1884. It was recoil operated and belt fed. The barrel recoiled three-quarters of an inch on a forward and rear bearing. This recoil operated the feeding belt and imparted the energy necessary for the bolt to free itself from the barrel, travel to the rear, fully extend the driving spring, and compress the firing-pin spring. The counterrecoiling bolt, actuated by the extended spring, ejected the spent cartridge, firmly grasped and chambered the cartridge to be fired, locked the bolt with the barrel, and freed the firing pin. Starting in 1888, Vickers Sons and Maxim, Ltd. produced the Maxim machinegun in great quantity until, eventually, the production model became better known as the "Vickers."

Maximum rate of fire.—The rate at which a weapon fires automatically and continuously; cyclic rate of fire when the period of measure is 1 minute.

Muzzle velocity.—The speed of a projectile at the instant it leaves the muzzle of a gun; a function of the amount and type of propellent charge, the length of the barrel, and the weight of the projectile.

Recoil operated.—The operating principle of a weapon which uses the energy of recoil to operate the extracting, reloading, and cocking phases. The weapon may be semiautomatic or automatic. The breech is locked at the moment of firing; the barrel and bolt assembly move to the rear together with the recoil and separate later.

Setback.—The rearward (relative) jerk, caused by inertia, of free-moving parts in a projectile when it is fired. This force may be used to push back a spring or plunger to start operation of a time fuze.

Shaped charge.—An explosive charge shaped so that the explosive energy is focused and concentrated to move in one direction, thus giving the projectile greater penetration. A hollow-cone charge is one form of a shaped charge.

JAPANESE ORDNANCE

The reader must realize, in considering Japanese ordnance, that Japan was one of the last countries to shed the cloak of feudal times and partake of the discoveries of the industrial revolution. For some 200 years, the feudal lords of Japan had handcuffed the Emperor and had closed Japan to all foreigners. At the time when the sanguinary Civil War was being fought in America, the only guns known to the Japanese were antiquated pistols, muskets, and cannon which had been obtained from the few Dutch who were permitted to trade at one of Japan's southern ports or the even more primitive weapons which had been obtained from earlier European explorers and traders before the period of self-imposed exile. When this period of feudal isolation was ended with the restoration to the throne of Emperor Meiji in 1867, the Japanese set out with fervent zeal to catch up with the rest of the world which had passed them by.

One of Japan's first considerations was to build up her armed forces. The still-revered traditions and code of the warrior were great assets toward this end and stood the Mikado's forces in good stead even as late as World War II. By 1895, Japan had already fought the Chinese, often mentioned as the inventors of gunpowder, and had annexed Formosa and the Pescadores. In 1904, Japan saw fit to engage Imperial Russia in war. A little more than a year later, the entire Russian fleet was destroyed at the Battle of Tsushima Bay—one of the major naval disasters of modern times until the United States and her Allies were able to turn the tables in the Pacific battles of World War II. By 1905, in the 38th year of the reign of Emperor Meiji, the Japanese had already developed and were manufacturing a basic rifle for its ground soldiers which was quite comparable to the then new U.S. Springfield, M1903. This model 38 rifle was the mainstay of Japanese troops during World War II. With her nearly constant warfare against the Chinese for some 50 years, with wars and skirmishes against Imperial and Soviet Russia over a period nearly as long, and with her participation in World War I on the side of the Allies, Japan had gained extensive knowledge in the arts of modern warfare. While circumstances dictated that her weapons be copies of those used by the world's leading powers, they were modified to suit her needs, and the Emperor's arsenals were quite complete with the gamut of modern weapons at the time of the dastardly strike at Pearl Harbor.

In evaluating both the weapons to be described and the casualty surveys which form later chapters of this volume, the reader should bear in mind that the Japanese Army was built around the foot soldier, just as the armies of the feudal lords of a not too distant past. Accordingly, the design of Japanese

weapons featured lightness and mobility. Supporting weapons were specifically designed as aids to the infantry. Tactical doctrine specified that the aim of all battle was for the foot soldier to engage the enemy and completely annihilate him. In offense or defense, the aggressiveness of the feudal warrior was the keynote, even to the extent of the final banzai raid when all was hopelessly lost.

This overdevotion to aggressive conduct of battle and adherence to the role of the infantrymen predominated in the consideration of an overall weapons system, and many forms of weapons were sacrificed or underdeveloped because of this concept. Thus, the weapons of the infantrymen were well developed and quite adequate to the extent that the mortars of the Japanese Army were more numerous in kind and number than in any of the armies engaged in World War II. At the same time, considerably less attention was given to larger artillery pieces, to AA (antiaircraft) artillery, and to AT (antitank) weapons.

The theme of lightness is quite evident when Japanese weapons are compared with the comparable U.S. weapons of World War II. The bore of Japanese rifle was 0.256 inch, while the United States had used an 0.30-inch bore for years. American submachineguns fired snub-nosed 0.45-inch bullets, while the Japanese guns fired 0.315-inch missiles. The same was generally true of pistols. The standard caliber of Japanese light machineguns was, as was that of the rifles and carbines, 0.256 inch, which corresponded to the American light machinegun of 0.30 inch. Japanese heavy machineguns, however, equalled in bore sizes those used by the U.S. Army. A similar analogy can be made with artillery. The basic gun of the Japanese infantry division, as encountered by the Allies in combat, was 75 mm. Division artillery of U.S. infantry divisions was 105 and 155 mm. Only in mortars did the Japanese foot soldier possess both smaller and larger bores at the advent of World War II. The most commonly encountered Japanese mortars were 81 and 90 mm. Standard U.S. mortars used by the infantry were 60 and 81 mm.

Another consideration in the Japanese design of lighter, smaller weapons was the combat for which they were designed. The weapons were adapted to the use of unmotorized units chasing inadequately armed Chinese over great expanses of countryside; they were particularly useful in jungle fighting and in the type of terrain which was encountered throughout most of the earlier fighting in the Pacific. An omen which was insufficiently heeded, or which could not be followed through, was the definite inadequacy of these weapons in more conventional warfare as pointed out in large-scale border skirmishes against Soviet forces in northern Manchuria and Siberia just before World War II. As the war progressed from the smaller islands and isolated areas of the Pacific and moved ever closer to the homeland, Japan had to manufacture larger bore weapons and better AA artillery and AT guns. But, by this time, Allied bombers had taken their toll of Japan's manufacturing potential.

While Japanese infantry weapons ultimately reached bore sizes close to

those used by U.S. forces, Japan developed but never produced a semiautomatic rifle or automatic carbine; hence, the Japanese soldier could not match the tremendous advantage in firepower which the American soldier held over him. Japanese artillery never reached the stage where it could lay down massed fires and rolling barrages as did U.S. artillery. It still remained aimed fire or, at most, point fire at the close of the war. It is doubtful whether Japanese logistics could have ever supplied the ammunition for such weapons or artillery practices, had they been feasible. As it was, the last months of World War II found the Japanese using mortars improvised from whatever was available, and captured documents explained in detail how such improvisations could be made by units in the field. More than 5 years after the Japanese surrender, the United States was to rediscover in Korea that these same Japanese weapons in the hands of Chinese Communists were still quite effective.

Edged Weapons, Hand Actuated

Although bayonets were attached to most Japanese rifles, they were not considered a primary cause of wounds. Among the 2,335 casualties studied in the Bougainville campaign, only 2 were listed as having had wounds caused by this weapon. A New Georgia-Burma casualty survey unit studied 393 casualties. Of 319 of these casualties that required hospitalization or that were killed in action, there were only 3 bayonet-wound cases. Two of these were accidentally inflicted with a U.S. bayonet, and in the third case the bayonet wound was secondarily inflicted following primary small arms wounds to the lower extremities. Notwithstanding this relatively small sampling of the total U.S. casualties incurred against the Japanese forces, it would appear that the bayonet was not a major, primary wound-producing weapon and that most bayonet and knife wounds were secondarily inflicted following a primary-missile wound. Infantry personnel through their personal experiences could probably reveal some variations as to the comparative effectiveness of bayonets and knives, but, in general, edged weapons were relegated to secondary functions.

Small Arms

Pistols and revolvers.—Japanese ground forces utilized several models of an 8 mm. semiautomatic pistol and of one obsolescent 9 mm. revolver. The Japanese Nambu, 8 mm. (0.315 in.) semiautomatic pistol, was named for its inventor, Col. Kijiro Nambu, and before 1925 was the standard sidearm in the Japanese Army. The weapon was recoil operated and magazine fed with the 8-round magazine fitting into the butt similar to the U.S. service automatic, caliber .45. Notwithstanding its independent development by the Japanese, the pistol had a superficial resemblance to the German Luger automatic. Originally, a separate shoulder stock was issued which, when attached to the butt of the pistol, enabled it to be used as a light carbine.

The Nambu used an 8 mm. bottlenecked semirimless cartridge. Its muzzle velocity was about 950 f.p.s. (feet per second) with maximum ranges, published in several sources, varying between 547 and 1,400 yards. Effective range was from 50 to 75 yards.

A 7 mm. (0.276 in.) model was also manufactured and represented a scaledown version of the 8 mm. model.

In 1925, the Model 14, 8 mm. semiautomatic pistol (fig. 1), replaced the Nambu as the standard sidearm and represented a further development of the earlier model. The Model 14 possessed a few external and internal modifications which facilitated the mass production of the weapon, but it used the same type of ammunition as, and had ballistic characteristics similar to, the Nambu.

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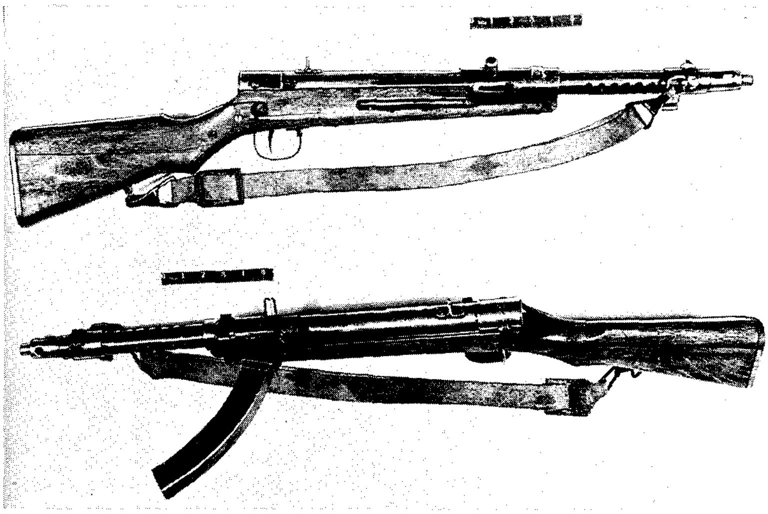
FIGURE 1.—Model 14 (1925) 8 mm. pistol.

The Model 94 (1934) 8 mm. semiautomatic pistol was of later design and manufacture, but it was considered inferior to the Model 14 (1925) in manufacturing quality and pointing properties. A dangerous feature of this model was that the weapon could discharge following rough handling without any manipulation of the trigger. It used the same type of 8 mm. ammunition as the Nambu and Model 14 pistols and had ballistic characteristics standard to this type of cartridge.

Submachineguns.—The basic design of Japanese submachineguns closely resembled corresponding German weapons as was well demonstrated in the standard 8 mm. submachinegun, Type 100 (1940). The Japanese had two modifications of this gun. The early model was designated the Paratrooper's Submachine Gun and was a light, blowback, bolt-action operated automatic weapon which fired the regular issue bottlenecked 8 mm. pistol cartridge. The

stock was cut through and hinged just behind the receiver and could be swung forward to lie parallel with the barrel. The curved box magazine had a capacity of 30 rounds, and the gun had an estimated cyclic rate of fire of 400 to 1,000 rounds per minute. The muzzle velocity was about 1,100 f.p.s.

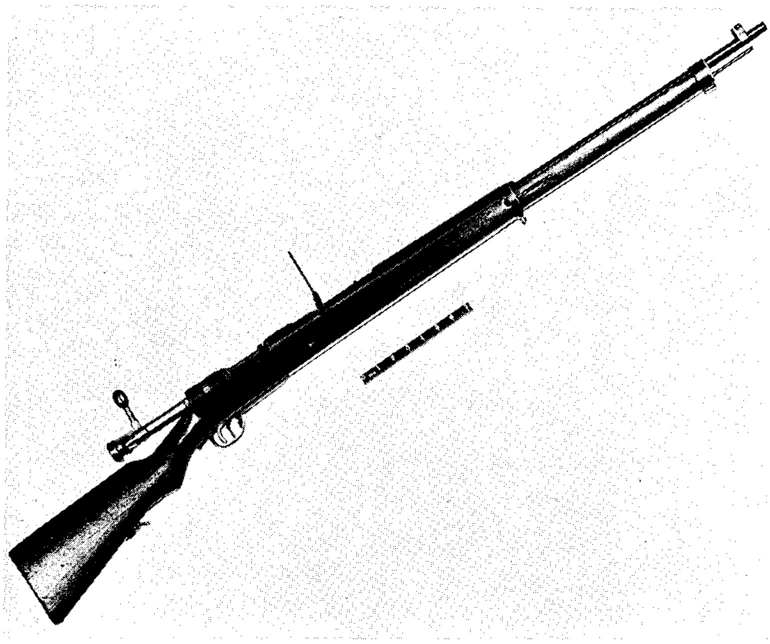
The later model (fig. 2) differed from the Paratrooper's Model 100 in the absence of the folding stock, fixation of the rear sight, alteration in the bayonet fixture, and some minor modifications in the principle of operation. It had a straight blowback operation, and the curved box magazine held 30 rounds of standard 8 mm. pistol ammunition. The estimated cyclic rate of fire was from 800 to 1,000 rounds per minute with a muzzle velocity of nearly 1,100 f.p.s.



OCO, D/A A18645

FIGURE 2.—Model 100 (1940) 8 mm. submachinegun, late model.

Rifles and carbines.—Japanese rifles and carbines developed for ground troops before 1939 were 6.5 mm. (0.256 in.) in caliber (fig. 3), while the models issued after that date showed a trend toward a 7.7 mm. (0.303 in.) rifle. At one time, the Model 38 (1905) (Arisaka) 6.5 mm. rifle was the basic Japanese infantry weapon, and it continued to be used during World War II despite the development of other models. This weapon was a modified Mauser-type rifle with a manually operated bolt action and was designed to fire ammunition of medium velocity. Its length was 50.39 inches without bayonet, and it weighed only 9 to 9¼ pounds without sling or bayonet. The mechanism of Model 38 was strong and sturdy, and, in its action, it was very similar to the U.S. rifle, M1903 (Springfield). Two noteworthy characteristics of the Model 38 were the slight amount of recoil and the minimal muzzle flash. The Arisaka fired ball, tracer, or a reduced-charge (practice) ball-type ammunition with a muzzle velocity of 2,400 to 3,000 f.p.s. and had an extreme range of over 4,000 yards. The rifle's effective range was from 400 to 500 yards.



OCO, D/A 76111

FIGURE 3.—Model 38 (1905) 6.5 mm. rifle, showing bolt open and rear sight leaf up.

A carbine, Model 38 (1905), was also produced with the same operating mechanism as the rifle, Model 38. It, however, was only 38 inches long and and weighed about 7½ pounds. It was equipped to hold the Model 30 bayonet and, like the rifle, was magazine fed from a 5-round clip. The ammunition was of the Model 38, 6.5 mm. ball and reduced-charge (practice) ball types. Muzzle velocity and maximum range were slightly less than for the Model 38 rifle because of the decreased barrel length.

Another carbine model which evolved from the Model 38 was designated the Model 44 (1911) 6.5 mm. cavalry carbine. It had the same bolt action, trigger mechanism, and receiver as the Model 38 rifle, but the bayonet was of the permanently attached folding type. The carbine, with bayonet folded, measured 38½ inches and weighed about 8½ pounds.

A sniper's rifle, Model 97 (1937), was also based on the Model 38 rifle and had a folding monopod, turned-down bolt handle, and telescopic sight.

In some of the battle areas during World War II, the Model 99 (1939) 7.7 mm. (0.303 in.) rifle began to replace the Model 38 (1905) as the basic Japanese infantry weapon. While still a manually operated, bolt-action, 5-round-clip weapon, it was only 44 inches long and weighed approximately 8½ pounds. In addition, it had a folding monopod, AA leading sight arms, and a hand guard extending to the front end of the stock. It used 7.7 mm. Model 99 (1939) rimless ball-type ammunition with the projectile weighing 181 grains. The muzzle velocity was about 2,390 f.p.s., with a maximum

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range estimated between 3,000 and 4,500 yards and an effective range of 450 to 600 yards.

Two modifications of the Model 99 were the paratrooper rifle, Model 99, and the paratrooper rifle, Model 2 (1942). Both weapons had the same operating mechanism and utilized the same ammunition as the parent rifle but were designed to incorporate a takedown feature which facilitated their use by paratroop units.

Machineguns.—One of the earlier types of Japanese light machineguns which saw service in World War II was the Model 11 (1922) 6.5 mm. machinegun. This weapon derived its model number from the fact that it was issued in 1922, the 11th year after the accession of Emperor Taisho in 1911. The gun was patterned after the Czech Brno machinegun and was gas operated with automatic fire only. One of its distinguishing characteristics was the feed hopper on the left side which held six 5-round rifle clips of Model 38, 6.5 mm. ball ammunition. The muzzle velocity was between 2,300 and 2,400 f.p.s., with a maximum range of over 4,000 yards and an effective range between 600 and 800 yards. The cyclic rate of fire was 500 rounds per minute and the effective rate from 120 to 150 rounds per minute.

The more commonly encountered 6.5 mm. light machinegun was the Model 96 (1936) (fig. 4). This model, like the Model 11, followed the Czech Brno

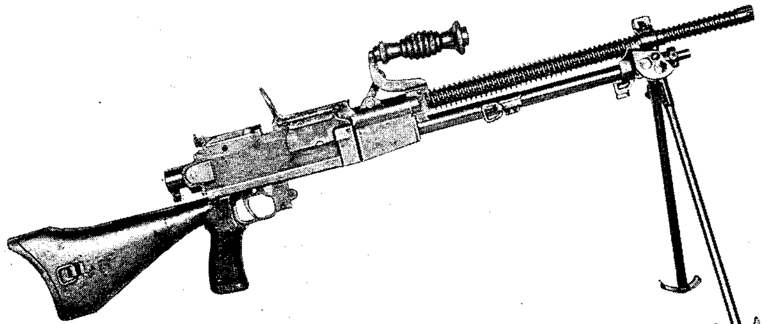

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FIGURE 4.—Model 96 (1936) 6.5 mm. light machinegun.

principle of operation and also had its outward appearance. It was still a gas-operated automatic weapon, but the feeding device was improved to accommodate a curved box holding 30 rounds of the Model 38 reduced-charge ball tracer ammunition. The rate of fire was increased to a maximum rate of 550 rounds per minute and an effective rate of 120 to 150 rounds per minute.

One model of a 6.5 mm. heavy machinegun recovered in small numbers from the Pacific battle area, Model 3 (1914), contained many parts which could be interchanged with the 7.7 mm. heavy machinegun, Model 92 (1932).

Because of a smaller feedport, however, the Model 3 could not be converted to fire 7.7 mm. ammunition. It was a gas-operated, air-cooled automatic weapon, and its feeding device consisted of metal strips containing 30 rounds of Model 38, 6.5 mm. ball ammunition. The muzzle velocity was 2,434 f.p.s., with a maximum range of 4,376 yards and an effective range of 1,500 yards. It had a rather low cyclic rate of fire of 450 to 500 rounds per minute and a practical rate of 200 rounds per minute.

Following the trend from the 6.5 mm. (0.256 in.) to the 7.7 mm. (0.303 in.) weapon, the 7.7 mm. light machinegun, Model 99 (1939), was developed from the 6.5 mm. Model 96. Basically, the two weapons were identical in principle of operation and feeding, but the Model 99 used the 7.7 mm. rimless ball ammunition. The muzzle velocity was around 2,300 f.p.s., with a maximum range of 3,800 to 4,500 yards and an effective range of 600 to 1,000 yards. The cyclic rate of fire was from 550 to 850 rounds per minute. The effective rate was from 120 to 250 rounds per minute.

A modification of the Czech Brno gun was issued as the Japanese Model 97 (1937) 7.7 mm. tank machinegun. This was a gas-operated, air-cooled automatic weapon that was designed for a tank mount but was available with conventional sights and a bipod so that it could be used from ground positions. A vertical box magazine held 30 rounds of Model 99, 7.7 mm. rimless-type ammunition, and the cyclic rate of fire was approximately 500 rounds per minute.

The standard Japanese 7.7 mm. heavy machinegun for ground forces consisted of two models, the Model 92 (1932) and the Model 01 (1941). Model 92 was a modified Hotchkiss-type, gas-operated, air-cooled automatic weapon with a metal-strip feeding device holding 30 rounds. It used Model 92, 7.7 mm. semirimmed ball, AP (armor-piercing), and tracer ammunition. Model 99, 7.7 mm. rimless-type ammunition could be used if loaded in strips. The muzzle velocity was estimated at 2,400 f.p.s., with a maximum range of 4,587 yards and an effective range of 1,500 yards. Normal cyclic rate of fire was from 450 to 500 rounds per minute, and the effective rate was from 150 to 250 rounds per minute.

The Model 01 (1941) was a direct modification of the Model 92 (1932) with the primary changes involving the overall dimensions and weight of the weapon. A total reduction in weight of approximately 41 pounds was made in the gun and tripod mount, and the barrel was shorter, with a resultant decrease in muzzle velocity. Both guns used the 30-round metal-strip feeding device, but the Model 01 used rimless ball, tracer, and AP ammunition.

A 7.7 mm. machinegun of the standard Lewis design was identified in several areas and was standard in the Japanese Navy. This machinegun, Model 92 (1932), had the Lewis gas-operated system and used a 47-round drum as the feeding device. It fired the 7.7 mm. rimmed Navy ammunition, which was the same as the British .303. Muzzle velocity was 2,400 f.p.s., with a maximum range of 4,000 yards or more and an effective range of 500 yards. The cyclic rate of fire was 600 rounds per minute.

With the strafing of ground troops by enemy aircraft, the identification of aircraft-type machineguns was of some value. The following is a list of some of the major models:

1. Model 89 (1929), a 7.7 mm. fixed aircraft machinegun. This gun was a copy of the British Mark V (caliber .303 Vickers-Maxim type).
2. Model 98 (1938), a 7.92 mm. flexible aircraft machinegun. Certain principles of design and operation not seen previously in Japanese weapons were employed in this gun, which actually was the German MG 15 manufactured in Japan. It had a cyclic rate of fire of approximately 1,000 rounds per minute.
3. A 12.7 mm. (0.50 in.) fixed aircraft machinegun which was a close copy of the U.S. .50 caliber Browning aircraft machinegun, M1921.

Grenade Dischargers

The grenade discharger was designed for use by the individual soldier and served to extend the range of the hand grenade as an intermediary weapon approaching the true mortars. It had a curved baseplate which made it appear as though it could be fired while the weapon was resting on a part of the human body and, therefore, was frequently, but incorrectly, referred to as the "knee mortar." Actually, the baseplate was made to fit over a tree trunk or a log or to be stuck into soft earth. The weapon was never intended to be fired while resting against the thigh, as some gullible individuals discovered to their dismay.

The 50 mm. grenade discharger, Model 10 (1921), was a steel, smoothbore weapon with an overall length of 20 inches, a barrel length of 9½ inches, and a total weight of 5¼ to 5½ pounds. The ammunition, a Model 91 hand grenade with safety pin removed or a pyrotechnic grenade, was inserted into the muzzle. Upon pulling an external trigger lever, the propellent train was ignited. The setback activated and armed the fuze. With the Model 91 hand grenade, the estimated range was from 65 to 250 yards.

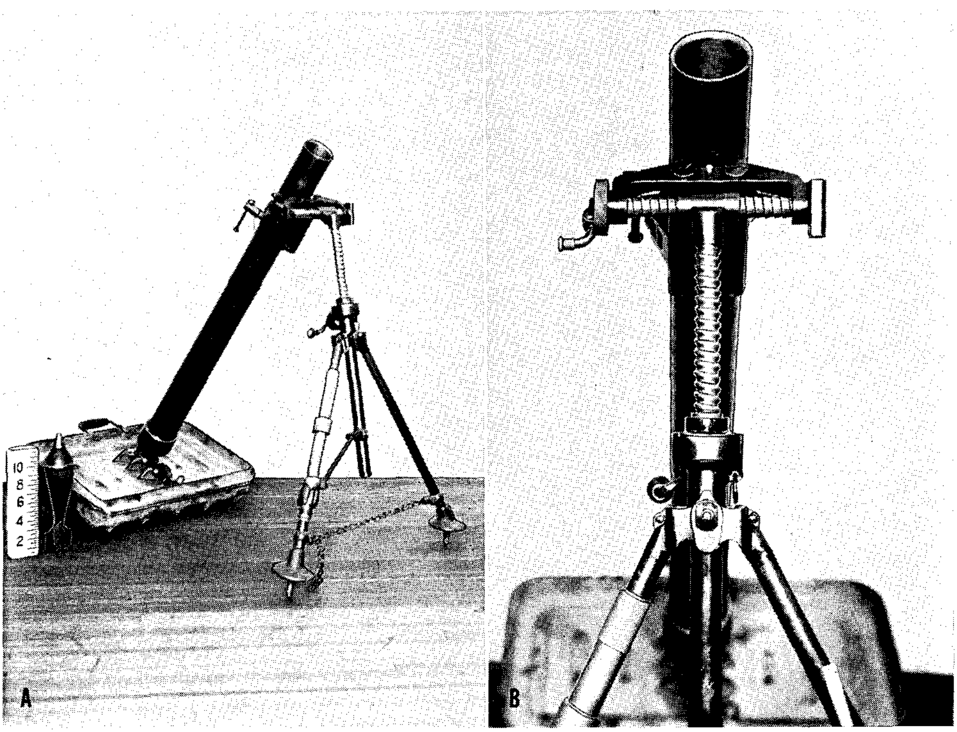
In 1929, the Japanese perfected the 50 mm. Model 89 grenade discharger which was an improvement over the Model 10. The discharger had an overall length of 24 inches, the barrel measured 10 inches, and the total weight was 10¼ pounds. A distinguishing feature of the barrel was its rifling. A Model 89 HE (high explosive) shell was designed with a rotating band which expanded against the rifling. In addition, the Model 91 hand grenade could be used as ammunition. The Model 89 HE shell had a range of 131 to 710 yards, and the Model 91 hand grenade had a range of 44 to 208 yards.

Mortars

Intermediate between the grenade dischargers and more conventional mortar designs was the 70 mm. mortar, Model 11 (1922). This weapon had a rifled tube and fired an HE projectile of the same design as that used in the Model

89 grenade discharger. The propellent charge was contained within the base of the projectile, and firing was accomplished by the impact of a percussion hammer against the firing pin. The weapon had an approximate range of 1,700 yards.

The most commonly encountered Japanese mortars were 81 mm. and 90 mm., and they were very similar in appearance to the U.S. 81 mm. mortar, M1. Among the 81 mm. mortars were two models, Model 97 (1937) and Model 99 (1939). The Model 97, 81 mm. mortar (fig. 5) was operated in the same

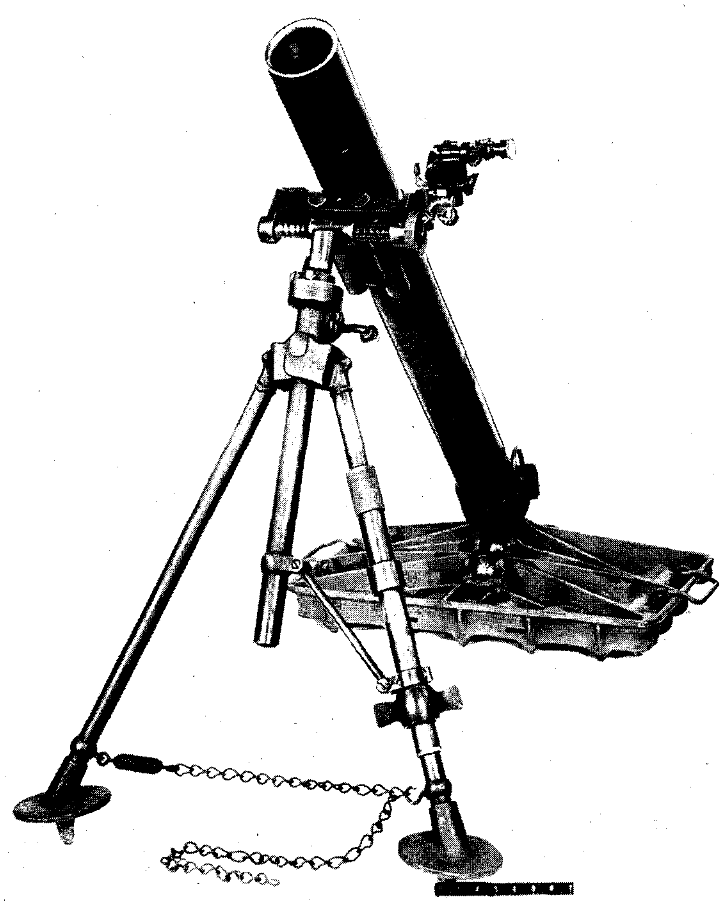


OCO, D/A 98392

FIGURE 5.—Model 97 (1937) 81 mm. infantry mortar. A. Three-quarter front view with shell next to baseplate. B. Close view of elevation mechanism.

manner as the U.S. 81 mm. mortar and used an HE shell, Model 100, weighing 7.52 pounds. The shell was also similar in appearance to the U.S. 81 mm. M43A1 mortar shell. Model 99 was a smoothbore mortar which weighed only 52 pounds but was found to fire a 7.2-pound shell approximately 2,200 yards. The projectile for Model 99 was again similar to the U.S. M43A1 ammunition, and the two forms were found to be interchangeable. One distinguishing feature of the Model 99 mortar was a movable firing pin which was brought into action by striking a firing-pin camshaft with a mallet.

Of the 90 mm. mortars, the prototype was the Model 94 (1934). This was a smoothbore, muzzle-loading weapon which was characterized by its heavy recoil mechanism. This mechanism furnished greater stability with higher powder pressures but increased the weight of the weapon to 353 pounds. The mortar had a fixed firing pin and was fired in the same manner as the U.S. 81 mm. mortar. Its HE rounds weighed 11.9 pounds. The approximate range was 4,050 yards. A Model 97, 90 mm. mortar (fig. 6) was issued in 1937 and had the same general appearance as the Model 97 (1937) 81 mm. mortar. It differed from the Model 94 mortar in the absence of the heavy recoil mechanism and tube reinforcing hoop and weighed 120 pounds less. Otherwise, it fired the same ammunition as the Model 94 and apparently had the



OCO, D/A A19573

FIGURE 6.—Model 97 (1937) 90 mm. mortar with telescopic sight as commonly used on most Japanese mortars.

same range. If instantaneous contact action was not required, a delay element could be placed in the nose of the fuze.

In addition to these commonly found mortars, the Japanese had others of conventional design in 120 and 150 mm. sizes with unconfirmed estimates of ranges as high as 5,000 yards. For sheer size, the Japanese had a 320 mm. spigot mortar which fired a 674-pound shell. Ammunition for a 250 mm. spigot mortar reportedly produced a radius of burst of 273 yards. In these models of the mortar, the Japanese principle of the heavy shell—that is, designing weapons to fire the largest possible shell from the lightest possible weapon—was expressed in its most extreme form.

Artillery, Conventional Guns, and Howitzers

Because of her complete isolation for such a long period of time, Japan ranked far behind other nations in the development of modern artillery weapons and tactics. Her artillery program was instituted in 1905 with the production of two types of field guns and two types of howitzers. These were identical to, or modifications of, European designs, as was her artillery of later times. As stated earlier in this chapter, Japanese models were invariably lighter than their foreign counterparts. This lightness was achieved by reducing the weight of the tube, equilibrators, recoil system, and trails, which make up the bulk of the weight of conventional artillery. Sometimes, this practice resulted in a loss of range, and some accuracy was sacrificed. On the other hand, these sacrifices were more apparent than real. Most of the Japanese artillery which was used in any great numbers was light artillery. The supporting function of artillery dictated that it be brought as far forward as possible for employment. Furthermore, most of the fire was aimed fire which, at the same time, had to be observed fire. Thus, the decrease in range with the lightening of the pieces was not a great loss. Because of the absence of modern fire-control and fire-direction methods, Japanese artillery used much time and many rounds to register itself. It was not adequate for counterbattery, nor was counterbattery a real mission of Japanese artillery. Since Japanese AA artillery was also inadequate, the field artillery was very vulnerable to observation and destruction from the air. Consequently, Japanese artillery did not fire long from any one position and was kept constantly on the move as a passive measure to protect it from hostile counterbattery and aircraft. The greater accuracy which heavier equipment might have given was really not required when the registration of pieces was accomplished as it was and when firing sites were so frequently changed.

Japanese artillery, when it did fire, was deliberate and accurate.

Table 1 presents a fairly comprehensive listing of Japanese artillery which was used in World War II. Figure 7 shows one model of the 75 mm. class and figure 8, one of 105 mm.

TABLE 1.—*Japanese guns and howitzers used in World War II*

Weapon	Type	Caliber	Muzzle velocity	Maximum range
		Mm.	*F.p.s.*	*Yards*
Model 97 (1937)	AT rifle	20	2,640	5,450.
Model 98 (1938)	AA/AT automatic cannon.	20	3,000	7,000.
Model 96 (1936)	do	25	2,850	7,435.
Model 11 (1922)	Infantry gun	37	1,480 (HE)	
Model 94 (1934)	do	37	2,330 (APHE)	5,000.
Model 97 (1937)	AT gun	37	2,625	4,400.
Model 1 (1941)	do	47	2,735 (HE) 2,700 (APHE)	8,400.
Model 92 (1932)	Howitzer	70	650	3,060.
Model 31 (1898)	Mountain gun	75	[1]	[1].
Model 38 (1905)	Field gun	75	1,670 (HE)	9,000.
Model 38 (1905) (Improved).	do	75	1,640 (HE) 1,977 (pointed)	8,938 (HE). 13,080 (pointed).
Model 41 (1908)	Mountain (infantry) gun.	75	1,160	7,000 (HE).
Model 41 (1908)	Cavalry gun	75	1,672	11,600.
Model 90 (1930)	Mobile field gun	75	2,296	16,350.
Model 94 (1934)	Mountain (pack) gun	75	1,285 (pointed) 1,165 (shrapnel)	8,938 (pointed). 7,957 (HE).
Model 95 (1935)	Field gun	75	1,700 (pointed)	11,660 (pointed, HE).
Model 14 (1925)	do	105	2,033	14,500.
Model 38 (1905)	do	105	1,770	10,900.
Model 91 (1931)	Howitzer	105	1,450 (HE, pointed).	11,500 (HE, pointed).
Model 92 (1932)	Field gun	105	2,500 (HE, pointed).	20,000 (HE, pointed).
Model 99 (1939)	Mountain howitzer	105	1,150	6,000 (HE).
Model 38 (1905)	Howitzer	120	900	6,300.
Model 38 (1905)	do	150	900	6,450.
Model 4 (1915)	do	150	1,430	10,800 (HE, pointed).
Model 45 (1912)	Heavy army artillery	150	2,870	27,250.
Model 89 (1929)	Heavy artillery	150	2,250	21,800 to 27,450.
Model 96 (1936)	Field gun	150	[1]	28,400.
Model 96 (1936)	Howitzer	150	1,770	13,000 (HE, pointed).
Model 45 (1912)	do	240	1,300	11,000.
Model 90 (1930)	Railway gun	240	3,440	54,600.
Model 96 (1936)	Howitzer	240	[1]	15,300.
Model 7 (1918)	Short howitzer	305	[1]	13,000.
Model 7 (1918)	Long howitzer	305	[1]	16,600.

[1] Undetermined.

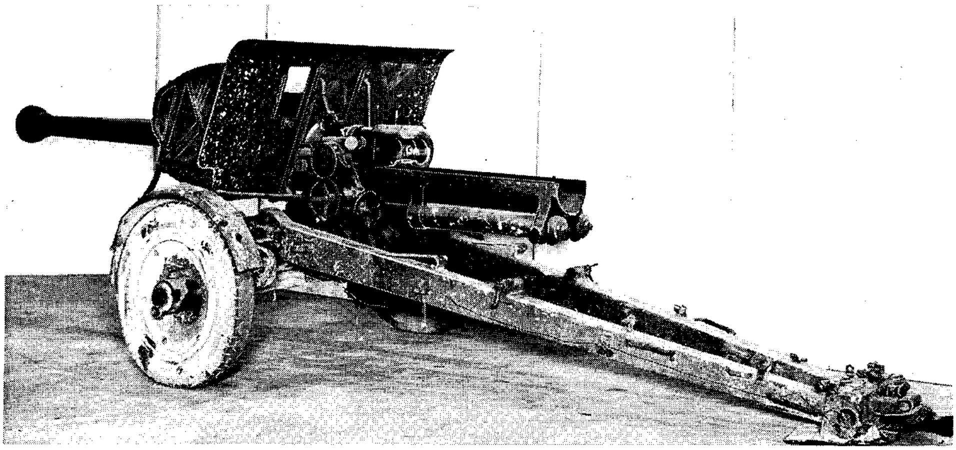


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FIGURE 7.—Model 90 (1930) 75 mm. gun, with high-speed carriage.

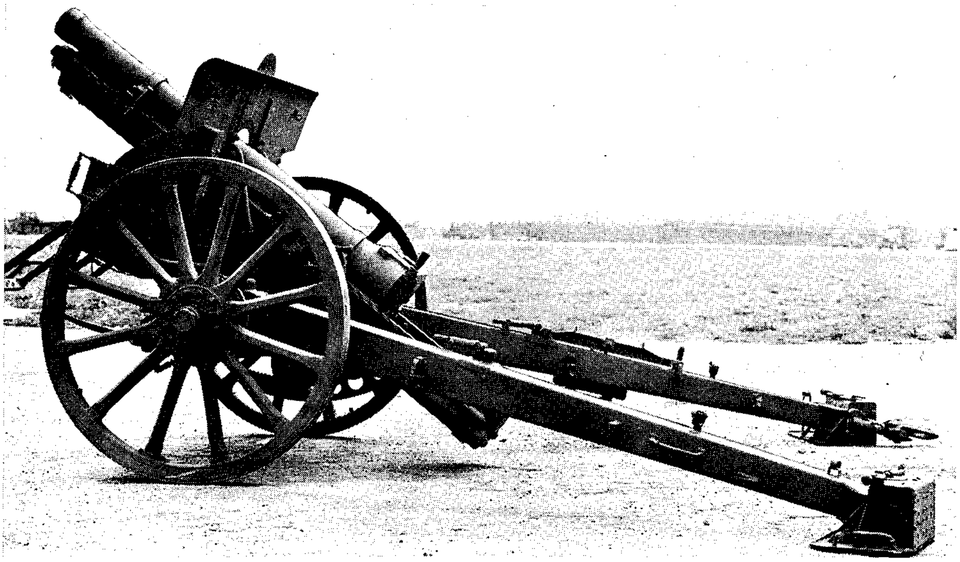

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FIGURE 8.—Model 91 (1931) 105 mm. howitzer.

Rocket Launchers

Japanese rockets and rocket launchers were of no great significance in World War II, although their development and production was rapid after they were introduced near the end of the conflict. Late models showed a strong German influence in their design. The early types of launchers for ground-to-ground rockets were crude metal or wood trough-shaped ramps of various lengths supported at the forward end by some simple form of bipod,

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usually iron pipe. Through German influence, these models were replaced by the tube-type launcher, some of which were supported by a light two-wheeled carriage with fixed metal frame. Rocket-assisted AA and aircraft missiles were still in the experimental stage at the end of the war.

Ammunition

For small arms.—The Japanese made both good and bad ammunition for use in their small arms. One of their principal problems was to keep the ammunition from "going bad" because of the dampness of the jungles. Much of the ammunition, especially grenades and mortar shells, was ruined because manufacturers tried to avoid waterproofing it. Good ammunition, often packed in flimsy crates, deteriorated through rough transportation and the influence of bad weather.

Small arms service ammunition (intended for actual combat use) was classified according to type as follows: Ball, AP, tracer, incendiary, and explosive. The ball type, oldest of the service types, was intended primarily for use against personnel and light materiel targets. Originally, the ammunition was shaped like a ball, but, with the advent of rifling in weapons, this ball was replaced by a cylindrically shaped bullet which would engage the rifling. The AP cartridge was intended to be used against armored aircraft and vehicles, concrete shelters, and other bullet-resisting targets. Incendiaries were used for incendiary purposes against aircraft and were sometimes combined with one or two of the other types. Tracers were intended to be used with other types to show the gunner, by their trace, the path of the bullets, thus assisting in correcting his aim.

The nose of most service rifle, carbine, and machinegun bullets was ogival (curved taper) and was round in those for pistols, revolvers, and submachineguns. The body in both types was cylindrical.

In the 6.5, 7.7, and 7.9 mm. classes, the Japanese had ball, AP, tracer, incendiary, and explosive types of ammunition. Ball, AP, and tracers were used in ground guns, while incendiaries and explosives were aircraft ammunition. There was also a ball ammunition with a core of mild steel, instead of lead, which was mistakenly referred to as semi-armor-piercing ammunition during the war. During the closing stages of the Iwo Jima operation, however, some use was made by the Japanese of 7.7 mm. explosive incendiary bullets in ground fighting. This condition became evident when some casualties were found to have one wound of entry and several wounds of exit. An explanation for this unusual condition was that aircraft ammunition may have been salvaged from grounded planes and air force depots and used when normal types of machinegun ammunition were no longer available. Cupronickel, steel, brass, copper, or zinc were the metals used in projectile jackets with cupronickel being used most often. No steel jackets were reported in the 8 mm. Nambu pistol cartridge.

The 6.5 mm. (0.256 in.) (fig. 9) bullet, especially one made with a gilding metal (an alloy of copper and zinc) jacket, when it hit a target had an explosive effect and tended to separate, leaving the entire jacket in the wound while the bullet went on through. Small globules of lead scattered through the wound and embedded themselves elsewhere in the flesh. This condition was the result of the fact that the rear-section walls of the bullet jacket, which was filled with a lead core, were thinner than the forward walls. The sudden stoppage of the high-velocity bullet when it hit an object produced a tendency to burst the rear walls causing an "explosion." The lead core, which had a greater specific gravity, penetrated, leaving behind the relatively lighter jacket from which it had been discharged. The bullets made with cupronickel jackets had more of a tendency to retain their lead cores because of the greater tensile strength of the alloy when compared with the strength of the gilding-metal-jacketed bullet.

The unusually large exit wound openings often found with this caliber bullet were due to the natural instability of the bullet and possibly to its being fired from inferior weapons. Similarly, there were elliptic entry wounds, a result of the "keyholing" effect of bullets hitting with their sides.

Table 2 gives a description of small arms ammunition. Weights of projectiles in the table will vary somewhat from figures given in other sources. This is true because manufacturers did not always load the cartridges in exactly

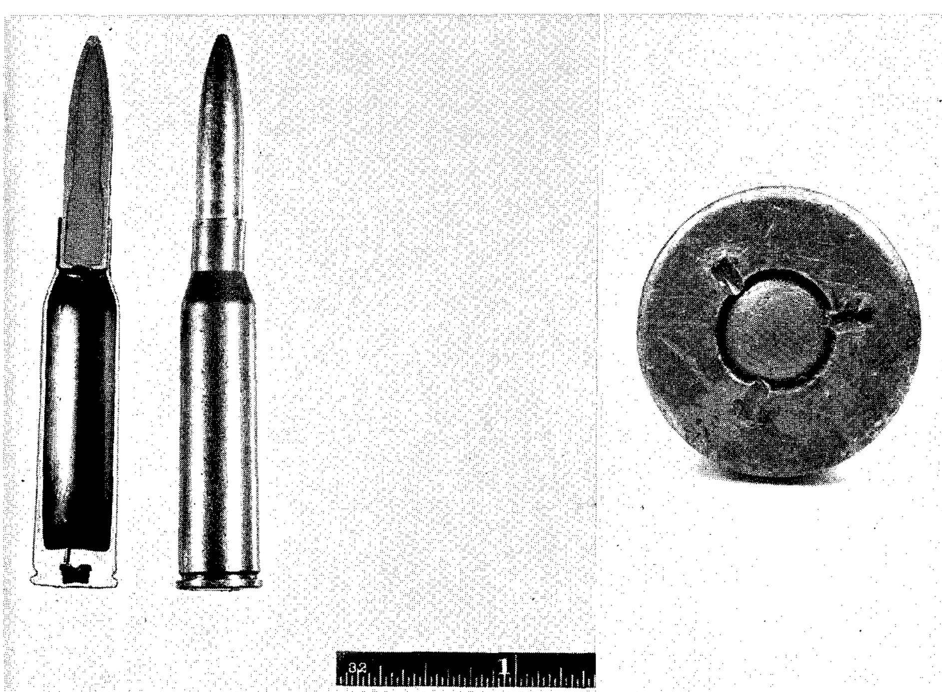

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FIGURE 9.—6.5 mm. ball ammunition.

TABLE 2.—*Japanese small arms ammunition*

Nomenclature	Caliber		Projectile				Weapons in which used
	Millimeters	Inches	Type construction	Core	Length	Weight	
					Inches	*Grains*	
Model 38 [1]	6.5	0.256	Ball	Lead	$1\frac{1}{4}$	138	Model 38 rifles and carbines, Model 97 rifle, Model 44 carbine, Model 11 light machinegun, Model 96 light machinegun, Model 91 tank machinegun, Model 3 heavy machinegun.
			Tracer	do			
Model 99 (rimless) [2]	7.7	.303	Ball	Lead	1.23	181	Model 99 rifle, Model 99 modified rifle, Model 2 rifle, Model 99 light machinegun, Model 97 tank machinegun, Model 92 heavy machinegun, Model 1 heavy machinegun.
			Tracer	do	1.23		
			AP	Hard steel	1.23		
Model 92 (Army semi-rimmed).	7.7	.303	Ball	Lead	$1\frac{25}{64}$	203	Model 92 heavy machinegun.
			Tracer	do	$1\frac{1}{2}$	155	
			AP	Hard steel	$1\frac{29}{64}$	162	
			Incendiary	White phosphorus and lead.	$1\frac{1}{2}$	162	
			HE	PETN [3] and lead	$1\frac{1}{2}$	162	
Aircraft machinegun [4] (Navy rimmed).	7.7	.303	Ball	Lead	$1\frac{9}{32}$	173.6	Model 92 heavy machinegun (Lewis type), Model 89 aircraft machinegun (Vickers type), Model 92 aircraft machinegun (Lewis type), Model 97 fixed aircraft machinegun (Vickers type).
			AP	Steel	$1\frac{13}{32}$		
			Tracer	Lead	$1\frac{13}{32}$	130.4	
			Incendiary	White phosphorus and lead.	$1\frac{13}{32}$	133.2	
			HE	PETN and lead	$1\frac{21}{64}$		
Aircraft machinegun	7.92	.312	Ball	Lead	$1\frac{7}{16}$	180	Bren light machinegun,[5] Model 98 aircraft machinegun, Model 100 aircraft machinegun, Model 1 aircraft machinegun.
			AP	Hard steel	$1\frac{29}{64}$	182	
			Incendiary	White phosphorus and lead.	$1\frac{29}{64}$	182	
			HE	PETN and lead			

Pistol	8	.315	Ball	Lead	19/32	102	Nambu, Model 14 and Model 94 pistols; Model 100 submachine gun.
Do	9	.354	do	do	5/8	150	Model 26 revolver.
						Ounces	
Aircraft machinegun	12.7	.50	do	do			Browning type aircraft machinegun, Model 1 (Browning type).
			AP tracer	Steel	1 3/4	1.25	Aircraft machinegun, Type 89.
			HE incendiary (fuzed Japanese).[6]	PETN incendiary and steel.	1 7/8	1.21	
			HE incendiary (fuzed Italian).[6]	do	2	1.35	
			HE incendiary (fuzeless).	do	2	1.16	
			Tracer	Steel			
			AP (Italian)	Lead tip, steel core	2 15/64	1.35	

[1] A wood-bullet round was used with the rifle to launch the rifle smoke grenade. A paper-bullet round was used to launch rifle grenades. The propelling powder used in the blank rounds was nitrocellulose, while in the other rounds, it was graphite-coated nitrocellulose.

[2] In addition to the usual brass cartridge cases, ammunition with a steel case was found.

[3] The PETN (pentaerythritol tetranite) in the HE round was set off by the heat of impact.

[4] Same as British .303.

[5] Bren light machineguns were captured from Chinese Nationalists.

[6] This ammunition was copied by the Japanese from the Italians. Of the two HE incendiary fuzed rounds, one was Italian and the other was a Japanese copy of it. The Japanese HE incendiary fuze differed from the Italian round in that the fuze used was of two-piece construction instead of one.

the same manner. Samples taken from different factory lots showed many slight variations.

For mortars.—Mortar shells were classified as HE, smoke, illuminating, practice, and training. However, only the HE type was of any concern in producing casualties. These are shown in table 3.

During the war, the South Pacific Area detonated 5 rounds of the Type 89, 50 mm. grenade discharger shell, 5 rounds of the Type 100, 81 mm. mortar shell (fig. 10), and 4 rounds of the Type 94, steel 90 mm. mortar shell in order to determine the frequency distribution of fragments from these missiles. The shells were fired statically in a vertical position with their noses approximately 1 inch in the ground. Panels of Celotex, 4-feet high and ½-inch thick, were placed in concentric circles with radii of 5, 10, 15, 20, 25, and 30 yards from the point of burst at the center. The panels in each circle covered only one-sixth of the circumference, thus making it possible to arrange them so that no panel obstructed any other panel in a circle of greater circumference. The number of hits for each circle, had it been possible to enclose it completely with 4-feet-high Celotex panels, was extrapolated from the hits observed on the assumption that the distribution of fragments was random. The results are shown in table 4. If the mean projected area of a soldier is taken as 4.2 square feet, the probable number of hits he would receive at various distances from the point of burst are shown in table 5. To paraphrase table 5 in terms of the

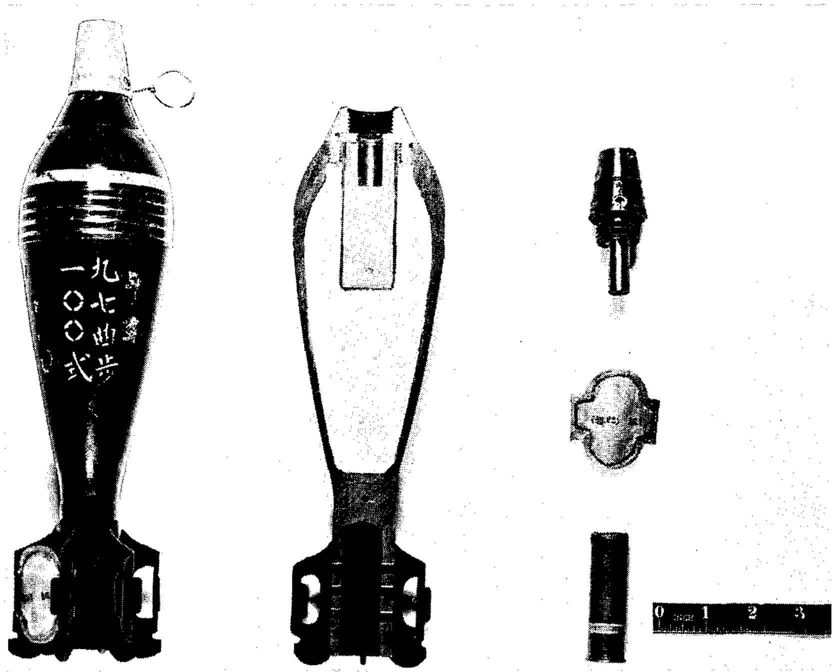

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FIGURE 10.—Model 100, 81 mm. HE mortar shell, showing ignition cartridge, propelling increment, and Model 100 fuze.

TABLE 3.—*Japanese mortar ammunition*

Nomenclature	Explosive components		Fuze	Weight (complete round)	Weapons in which used
	Main charge	Booster			
				Pounds	
HE mortar:					
Type 89, 50 mm	TNT		Small, instantaneous	1. 6	Type 89 grenade discharger.
Type 11-year, 70 mm	do	Picric	Instantaneous, short delay, mortar.	4. 28	Type 11-year, 70 mm. rifled mortar.
Type 97, 81 mm	do	do	do	7. 35	Type 97, 81 mm. mortar, and Type 99, 81 mm. mortar.
Type 100, 81 mm	do	do	do	7. 52	Do.
Type 94, 90 mm	do	Picric (pressured).	do	11. 8	Type 94, 90 mm. mortar and Type 97, 90 mm. mortar.
Type 94, 90 mm. semisteel [1]	do	[2]	do	11. 5	Do.
Type 2, 120 mm	do	RDX and wax	do	26. 5	Type 2, 120 mm. mortar.
Type 96, 150 mm	do	Picric	do	58. 66	Type 96, 150 mm. smoothbore mortar.
Type 97, 150 mm. [3]	do	RDX and wax	do	43. 5	Do.
Spigot-type mortar:					
32 cm	Picric	PETN	Interim	737	Special spigot-type mortar.

[1] This shell is similar in design to the Type 94, 90 mm. HE shell, except that it is made of low grade steel or semisteel instead of high grade steel.
[2] Data are not available.
[3] Except for its shorter size this projectile is similar in construction to the Type 96 HE long round.

probability of receiving one hit, a soldier at 6.5 yards from the point of burst would receive a hit from the Type 89 grenade; at 8.2 yards, from the 81 mm. mortar; and at 8.93 yards, from the 90 mm. mortar.

TABLE 4.—*Frequency distribution of Japanese grenade discharger and mortar shells*

Distance of panels from burst (radius of circle in yards)	Counted hits on panels [1]			Number of hits [2]		
	Type 89 grenade discharger (5 rounds)	81 mm. mortar (5 rounds)	90 mm. mortar (4 rounds)	Type 89 grenade discharger (1 round)	81 mm. mortar (1 round)	90 mm. mortar (1 round)
5	132	327	276	158	392	414
10	48	19	104	58	95	156
15	37	42	65	44	50	98
20	26	22	20	31	26	30
25	21	17	21	25	20	32
30	18	8	14	22	10	21

[1] Panels cover one-sixth of each circle.
[2] Calculated for full coverage of circles.

TABLE 5.—*Hit probability for human targets, Japanese grenade discharger and mortar shells*

Distance of panels from burst (radius of circle in yards)	Probable number of hits for type of shell		
	Type 89 grenade discharger	81 mm. mortar	90 mm. mortar
5	1. 56	4. 4	5. 7
10	. 39	. 55	. 7
15	. 17	. 16	. 21
20	. 10	. 07	. 09
25	. 06	. 04	. 05
30	. 04	. 02	. 03

The reader should note that this was just one test. Under different circumstances, results could also be expected to differ. For example, a mortar shell does not hit the ground perpendicularly when fired for effect. The more acute the angle a shell assumes when striking the ground, the more the distribution of fragments will vary from pure randomness in all directions. Those emanating from the upper surface will go high into the air, those from the sides will come closest to a random dispersion within limited bilateral areas, and those on the underside of the shell will imbed themselves in the ground. This results in a butterfly pattern of dispersion which is ascribed to many types of shells. While the foregoing experiment arrived at some figures for the dispersion of fragments from these Japanese missiles, it did not tell what the wounding capabilities of the hits were. This is the core of the subject of wound ballistics and will be fully developed in later chapters of this volume. Neither could the study just described determine by actual count the number

of fragments produced by each type of shell. Of the fragments which were recovered, their size was generally small, about one-eighth to one-sixteenth of an inch in diameter.

A study conducted in the Zone of Interior in December 1944, however, had as its purpose the recovery of as many fragments as possible from the detonations of each of five 81 mm. mortar shells. From 542 to 696 fragments per shell were recovered. The mean was 608.6 fragments per shell. This corresponds remarkably well with the sum of the entries in the column pertaining to the number of hits for the 81 mm. mortar calculated for full coverage of circles in table 4. Figure 11 shows the number, size, and shape of the fragments recovered from one of the five shells tested.

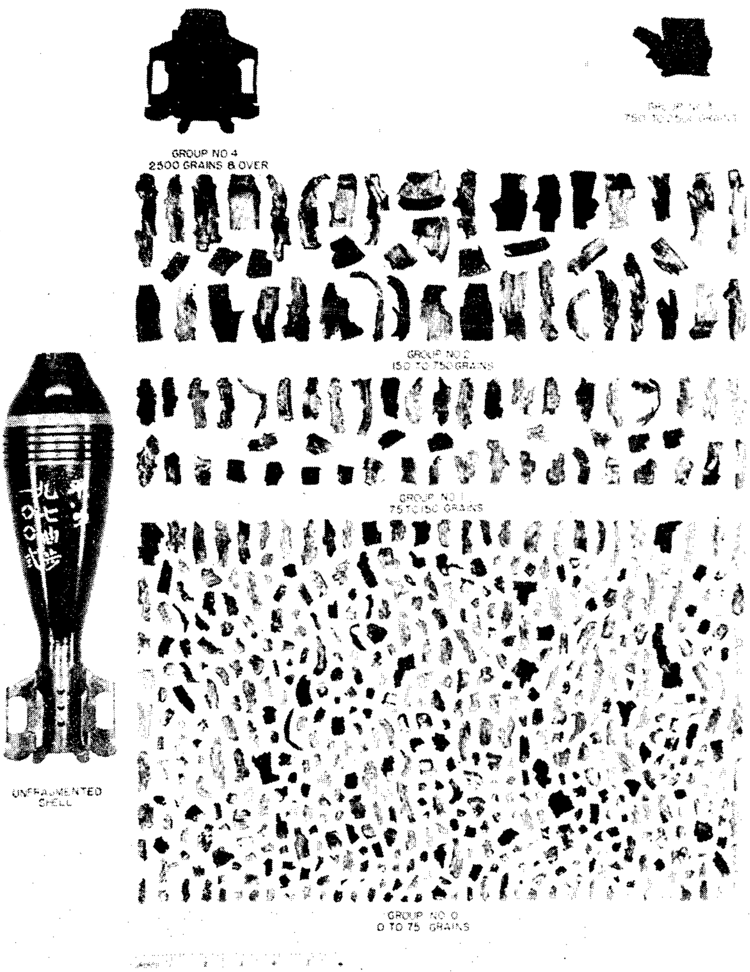


FIGURE 11.—Fragments recovered from Japanese 81 mm. mortar shell exploded under test conditions in Zone of Interior in December 1944.

The foregoing studies were presented to give the reader an appreciation of the wounding potential of Japanese mortar shells as he reads subsequent chapters of this volume. It would have been desirable to note the initial and terminal velocity of the fragments and their weight, since the actual wound production of a missile is, to a great extent, a function of its mass and velocity. These data were not available, unfortunately, but it can be assumed, based on the initial velocity of fragments from other mortar shells of similar properties, that the initial velocity of fragments from the Japanese 81 mm. shell was over 2,500 f.p.s. The weight of the fragments of the Japanese 81 mm. mortar shell can be estimated in that the average gross weight for one shell of fragments collected from detonations of the December 1944 test was 5.50 pounds. Thus, it took more than 100 fragments of the Japanese 81 mm. mortar shell to make 1 pound of steel. These data, taken in conjunction with the distribution data presented, should give the reader a good idea of the value of the mortar in ground combat—a weapon which was so fully exploited by the Japanese.

For guns and howitzers.—A Japanese artillery round was conventional in design with the usual components—projectile, fuze, propelling charge, and primer. The projectiles were cylindrical with ogival heads and could be classified as HE, AP, incendiary, tracer, or shrapnel according to their purposes and construction. Many embodied combinations of these elements. There were also hollow and shaped charges in the AT, AP types. Fuzes to detonate the projectile at the target were PD (point detonating) or BD (base detonating) according to their position on the projectile. They also differed as to whether the action was to be instantaneous, delay, or instantaneous-delay in combination.

With respect to the fuze action of enemy artillery shells, it should be noted that none of the Axis Powers possessed the proximity fuze, a device which permitted the airburst of shells. That is, the Axis forces could delay the detonation of their shells after impact, but they could not make them explode at predetermined altitudes over a target, except by time fuzes. An airburst is highly desirable because fragmentation then more evenly saturates the whole area of the shell's effective radius with pieces of steel. A shell striking the ground at an oblique angle with nose down, as explained in the preceding section on mortar ammunition, has a fragmentation pattern more or less limited to the lateral aspects. German attempts to achieve the airburst effect, without a mechanical time fuze, will be described in that section.

Japanese artillery rounds ranged in weight from a little over 1 pound for the smaller guns to well over 100 pounds in the heavy-artillery classes. The bursting charges were either TNT, picric acid, RDX (cyclonite) and beeswax, black powder, or dinitronaphthalene and combinations thereof. Many of the various types of shells could be used interchangeably in Japanese artillery if the bore size was comparable. Because of the many sizes and types, it would be neither feasible nor worthwhile to attempt a comprehensive survey of Japanese artillery ammunition here. Moreover, the most essential data concerning fragmentation characteristics could not be obtained. The lack of this

data greatly limits the value of any information which could be presented. Accordingly, only general features of the most commonly encountered types of Japanese artillery ammunition will be described. The data are presented in table 6.

Other Missile-Producing Agents

Grenades.—Because of its widespread use in the grenade discharger (knee mortar), the Japanese fragmentation hand grenade was responsible for a considerable number of casualties sustained by U.S. forces in the Pacific islands. The Model 91 (1931) (fig. 12) hand grenade was most versatile. It had a cylindrical cast iron body, 2.75 inches long and 1.97 inches in diameter, which was divided into 50 serrated segments. The bursting charge consisted of 65 grams of pressed TNT. When used as a hand grenade, the firing pin

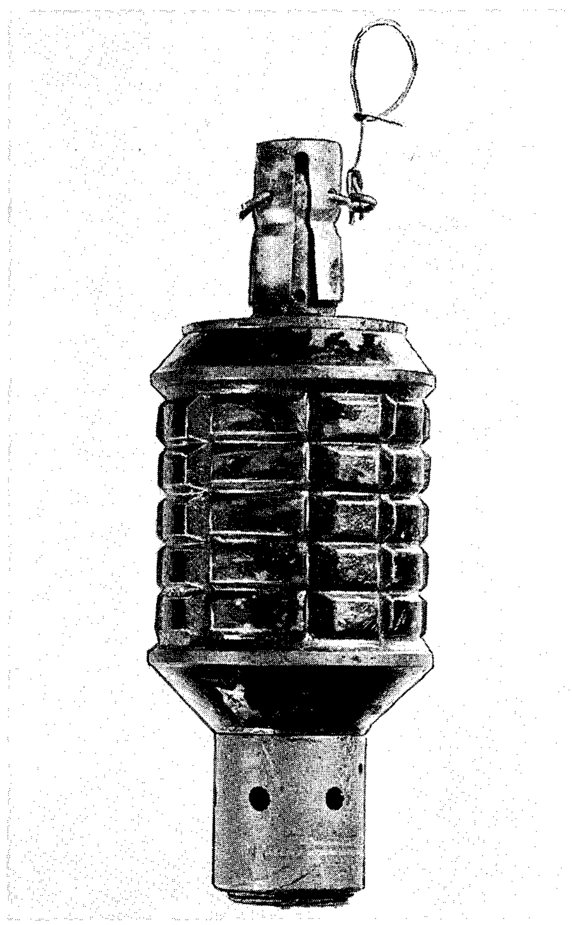


FIGURE 12.—Model 91 (1931) hand grenade.

TABLE 6.—*Japanese artillery ammunition commonly used*

Nomenclature	Type bursting charge	Weight (whole ammunition)	Fuze	Weapons in which used
70 mm:		*Pounds*		
M92 HE	TNT	8.38	M88 delay	M92 battalion howitzer.
M97 HE	do	8.63	M88 instantaneous and delay.	Do.
75 mm:				
M94 HE	do	13.27	do	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M94 mountain gun, M90 field gun, M95 field gun.
M94 HE	Ammonium nitrate, guanidine nitrate, cyclonite and TNT.	13.27	do	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M94 mountain gun.
M95 APHE	Picric acid and dinitronaphthalene.	13.69	M95 AP small base	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M94 mountain gun, M90 field gun.
M90 HE	TNT	12.59	M88 instantaneous and delay.	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M90 field gun.
M10 HE	do	12.35	do	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun.
Type "A" HE	Picric acid and dinitronaphthalene.	14.24	M3 combination	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M94 mountain gun.
Type "B" HE	do	14.57	M88 instantaneous and delay.	Do.
M90 or M97 HE	TNT	13.62	do	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M94 mountain gun, M90 field gun.
M90 shrapnel	Black powder	15.43	M5 combination	Do.

M38 shrapnel	do	15. 06	M3 combination	M41 mountain gun, M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M94 mountain gun.
M90 pointed HE	TNT	13. 98	M88 instantaneous and delay.	M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun, M94 mountain gun, M90 field gun.
M10 HE	do	14. 44	do	M38 field gun, M41 cavalry gun, M38 field (improved) gun, M95 field gun.
M87 HE	do	14. 33	do	M38 field (improved) gun.
APHE	Cyclonite and beeswax	14. 45	Base delay	M41 mountain gun.
M2 HEAT	Cyclonite and TNT (hollow charge).	8. 34	M88 instantaneous	Do.
M98 HE (improved).	TNT	([1])	M88 instantaneous and delay.	Do.
105 mm:				
M91 HE	do	35. 26	do	M91 howitzer, M92 field gun, M38 field gun, M14 field gun.
M91 HE	Ammonium nitrate, guanidine nitrate, and cyclonite.	34. 31	do	M91 howitzer, M92 field gun.
M95 APHE	Picric acid and dinitronaphthalene.	35. 06	M95 BD	M91 howitzer, M92 field gun, M14 field gun, M38 field gun.
M14 HE	TNT	35. 26	M88 instantaneous and delay.	M91 howitzer, M14 field gun, M38 field gun.
M91 HE	do	35. 26	do	M91 howitzer, M92 field gun, M14 field gun, M38 field gun.
M91 pointed HE	do	34. 74	do	Do.
M95 pointed HE	do	34. 74	do	Do.
M95 shrapnel	Black powder	36. 94	M5 combination	M91 howitzer.
M14 shrapnel	do	36. 94	do	M92 field gun, M14 field gun, M38 field gun.
M14 pointed HE	TNT	35. 26	M88 instantaneous and delay.	M14 field gun.

See footnote at end of table.

TABLE 6.—*Japanese artillery ammunition commonly used*—Continued

Nomenclature	Type bursting charge	Weight (whole ammunition)	Fuze	Weapons in which used
105 mm—Continued		*Pounds*		
Type "A" APHE	Picric acid and dinitronaphthalene.	39. 76	M88 base (for guns)	M38 field gun.
Type "B" APHE	do	39. 76	do	Do.
Type "A" cast iron APHE.	do	40. 18	do	Do.
Type "B" cast iron APHE.	do	39. 67	M88 No. 2 Base	Do.
Type "C" cast iron APHE.	Black powder	39. 17	do	Do.
M38 shrapnel	do	39. 67	M5 combination	Do.
150 mm:				
APHE	Picric acid and TNT	79. 34	M88 BD	M4 howitzer, M38 howitzer.
M95 APHE	Picric acid and dinitronaphthalene.	79. 08	M95 BD	Do.
Type "A" APHE (cast iron).	Picric acid and TNT	79. 34	M88 BD	Do.
Type "D" APHE (cast iron).	do	79. 34	do	Do.
M10 HE	TNT	79. 34	M88 instantaneous and delay.	Do.
M11 HE	do	80. 23	do	Do.
M92 HE	do	79. 34	do	Do.
M92 HE	Ammonium nitrate, guanidine nitrate, and cyclonite.	78. 46	do	Do.
M92 pointed HE	TNT	68. 54	do	M4 howitzer, M96 howitzer.
Type "A" shrapnel	Black powder	79. 34	M5 combination	M4 howitzer, M38 howitzer.

Type "B" shrapnel	do	79. 34	M88, 35-second combination or M5 combination.	Do.
APHE	Picric acid and dinitronaphthalene.	98. 98	M88 BD	M89 gun, M45 gun.
M95 APHE	do	101. 12	M95 BD	Do.
M93 HE	TNT	89. 48	M90	Do.
M93 HE	Ammonium nitrate, guanidine nitrate, and cyclonite.	88. 14	do	Do.
M93 pointed HE	TNT	88. 60	do	Do.
Shrapnel	Black powder	98. 96	M5 combination	Do.

[1] Data are not available.

NOTE.—In this table, "M" is used as an abbreviation for "Model."

was screwed down as far as possible, the safety pin removed, and the head of the grenade struck on a hard object—rock, shoe heel, helmet, and so forth—to activate the fuze. The delay was from 8 to 9 seconds. There was an opening in the base of the grenade into which could be screwed a steel propellent container when it was used in the grenade discharger or a fintail stabilizer when it was used as a rifle grenade. As a rifle grenade, a 6.5 mm. wood-bullet blank cartridge propelled the grenade from a spigot-type launcher which was affixed to the rifle. In both cases—as a projectile for the grenade launcher or as a rifle grenade—the setback initiated the fuze.

There were two other Japanese hand grenades of this same general design. One, the Model 97 (1937), was similar to the Model 91 grenade except for the fact that a solid base prevented its use in the grenade discharger or as a rifle grenade. This grenade also differed from the Model 91 in that it had only a 4- to 5-second delay, and it was 4 inches long and 2 inches in greatest diameter. A smaller grenade, Model 99 (1939 (Kiska)), had a smooth-surfaced cast steel body filled with picric acid. The overall length was 3½ inches; diameter, 1⅝ inches; and total weight, approximately 10 ounces. The fuze delay was from 4 to 5 seconds. Although the bottom of the body was solid, the Kiska grenade could be fired from a rifle with the use of a Type 100 launcher especially designed for this grenade.

Among other miscellaneous types of grenades, the Japanese had a stick-type (potato-masher) grenade which had a smooth cylindrical body of one-quarter of an inch cast steel and a wood handle. There was also an HE rifle grenade, Model 3, which could be fired from both the Model 38 and Model 99 rifles with a spigot-type launcher and the blank wood-bullet cartridge. While similar to the Model 91 hand grenade, it was smaller and had a smooth wall rather than the serrated body. The fuze for this rifle grenade was instantaneous upon striking an object.

Landmines.—The Japanese employed both AT and antipersonnel mines in greater numbers as defensive weapons as the war reached closer to their homeland.

The Model 93 (1933) (tape-measure) mine was a small circular-shaped mine 7 inches in diameter, 1¾ inches high, with four metal rings on each side for carrying or tying the mine in place. It weighed 3 pounds and had approximately 2 pounds of explosive within a sheet metal container.

The yardstick mine, so-called because it was exactly 36 inches long, was oval in cross-section and had four fuzes or pressure points. Its charge consisted of eight ¾-pound blocks of picric acid in a tin tube.

The Model 98 (1938) hemispherical antiboat mine was designed by the Japanese for beach defense against landing craft but was also used on land as an AT mine. It had a hemispherical appearance with two protruding, horn-like electrochemical fuzes. The body was of mild steel with two carrying handles. Total weight of the mine was 106 pounds, with 46 pounds of explosives. The single-horn antiboat mine (teakettle mine) was smaller, had only one horn, weighed 66 pounds, and contained 22 pounds of explosives.

The Model 99 AP mine was also called the magnetic AT bomb or the magnetic AP hand grenade. This mine was small, circular, 4¾ inches in diameter, and 1½ inches high. Four permanent magnets were fastened to its sides by khaki webbing to hold it in place against a metal surface until it detonated. It weighed 2 pounds and 11 ounces.

The Japanese also used several other types of mines which will not be discussed in detail here.

Boobytraps.—Most of the Japanese boobytraps encountered during the early stages of the war were constructed with ordinary hand grenades with friction-type fuze igniters or improvised electrical fuzes. Later, machine-made fuzes were also used. These fuzes were rigged to an explosive charge which would easily detonate when pressure was applied or when an electrical circuit was closed.

Ingenious methods were used to boobytrap the charges. Phonographs were wired using the pickup arm as an electric contact so that, when moved to play a record, a circuit to a charge beneath the floor would be closed. Hand grenades were often trip-wire-operated and either buried just below the surface or left lying on the ground in brush or rubble where troops could step on or kick them. Others were found attached to coconuts by means of a string. When the coconut was picked up, the grenade exploded. Bamboo poles were similarly fixed with the expectation that troops would pick up the poles to make huts. Common objects such as fruit cans, toothpaste tubes, flashlights, umbrellas, pipes, pistols, and soap were also boobytrapped. The Japanese were even known to place hand grenades or packages of picric acid in the armpits or underneath bodies of their partially buried dead to explode when the bodies were moved.

Bangalore torpedoes, used by the Japanese to demolish barbed wire entanglements, were occasionally also used as boobytraps. The torpedo consisted of an explosive charge placed into a piece of common iron pipe capped on both ends. To operate, the caps had to be removed and a fuze inserted in one end. Casualties resulted when American soldiers tried to use the pipes as crowbars or fire grates.

Distribution of Weapons

While the foregoing paragraphs have attempted to summarize the characteristics of Japanese ordnance, a true picture of its capabilities requires some information as to the distribution of weapons to units in the field. This is a very difficult picture to draw for any army because army organization is by necessity flexible and subject to frequent metamorphoses with changing circumstances and missions. In the Japanese Army, as in most of the armies of World War II, the division was the basic unit of the combined arms, and an inventory of its armament should give a good idea of the distribution of primary infantry weapons. Unfortunately, the situation is not so simple. There were many types of divisions. The writers of this chapter, after con-

siderable deliberation, chose to describe what has been called the Japanese triangular infantry division with RCT's (regimental combat teams). This choice was made since the surveys described in other chapters of this study relate to combat conditions in which this type of division organization was most probably used.

The RCT triangular division was specially organized for island warfare and differed radically from the standard and standard-reinforced triangular divisions. Its strength, somewhat less than the standard divisions, varied considerably according to the degree of reinforcement which was made. While the average strength of this division with only one of the combat teams reinforced was 13,600, it could range as high as 16,000. Table 7 presents the weapons of this type of division with one reinforced and two standard RCT's. The division troops included tank, signal, intendance, ordnance, land transportation and sea transportation units; a field hospital; and a water supply and purification section. A reinforced regiment had three infantry battalions, each with three rifle companies, one mortar company, one artillery company, and one engineer platoon; a machine cannon company; tank company; engineer company; signal company; and a medical detachment. A standard regiment in this type of division had three infantry battalions, each with three rifle companies and an infantry gun company; an artillery battalion; engineer company; signal company; transport company; and a medical detachment.

TABLE 7.—*Distribution of weapons in a Japanese triangular infantry division with 1 reinforced and 2 standard RCT's (regimental combat teams)*

Weapons	Reinforced RCT	Standard RCT	Standard RCT	Division headquarters and troops	Aggregate
Rifles	1, 950	1, 650	1, 650	900	6, 150
Grenade dischargers	108	108	108	4	328
Light machineguns	108	108	108	13	337
Heavy machineguns	18	18	18		54
20 mm. AT rifles	9			10	19
20 mm. AA machine cannon	6				6
37 mm. AT guns	6	6	6		18
70 mm. battalion howitzers		6	6		12
81 mm. mortars	54				54
75 mm. mountain guns	9				9
75 mm. field guns		12	12		24
Flamethrowers	7	4	4		15
Tank	9			17	26

The reader may have noticed that, in table 7, many of the previously described weapons are missing. Some of these helped make up the arms of a standard infantry division. In a standard infantry division, there was, for instance, a field artillery regiment with twenty-four 75 mm. field guns and

twelve 105 mm. howitzers. The regiments of the standard division had both 70 mm. battalion howitzers and 75 mm. regimental guns. The other weapons were in many different types of independent units, such as artillery regiments and mortar battalions, which usually made up army troops. (There was no Japanese corps organization similar to the corps organization in the U.S. Army. The Japanese field army had the tactical functions of a U.S. Army corps and the administrative and operational responsibilities of a U.S. field army.)

GERMAN ORDNANCE

The history of Germany in modern times closely parallels, in many respects, the history of Japan. At a time when the New World was being settled and the other powers of Europe were in their period of greatest territorial and commercial expansion, Germany was beset by internal strife. The country was split into small principalities and kingdoms for over 200 years following the Thirty Years' War (1618–48). It was not until the latter half of the 19th century that two powers arose which were strong enough to contest each other for control of all Germany. This struggle culminated in the Seven Weeks' War in 1866 which saw Prussia emerge on top. In 1867, the same year as the Meiji Restoration in Japan, a semblance of a united Germany came into being in the North German Confederation created by the Prussian Chancellor, Otto von Bismarck. In 1870, the establishment of the German Empire (Deutsches Reich) was proclaimed, and Wilhelm I of Prussia was made Emperor on 18 January 1871.

Unlike Japan, the German peoples had not let themselves become isolated from the rest of the world during this interim of internal conflict. The Prussian Army was first rate for its time and a victorious army in the fight for the control of Germany. By 1870, Bismarck was ready for war. It was a simple matter to trick Napoleon III of France into a war with the new German State, and it was an equally simple matter for the disciplined Prussian Army to defeat the demoralized French forces. France ceded Alsace and most of Lorraine to Germany by the Treaty of Frankfurt on 10 May 1871 and enriched the treasury of the just formed Deutsches Reich by paying an indemnity of 5 billion francs.

These successes firmly established the high position of Prussian officers in the government of the new State and guaranteed the establishment and maintenance of, what they hoped, was a second to none fighting machine as a part of the country's national policy. The military spirit became the fiber of the country; the military band, commonplace. The duel with swords was the most respected form for settling disputes between individuals and was the ultimate recourse for the preservation of one's honor. On such a political and sociological base was built a mighty force which rose to challenge the peace of Europe and the world in 1914. It required the combined might of the

Allies to stop this force in 1918, but the Treaty of Versailles did not destroy the spirit of militarism nor the men who possessed the know-how to conduct such a war. Shackled and frustrated during the period of the German Republic, the military spirit emerged afresh with Hitler's establishment of the Third Reich. The somber strains of Deutschland Uber Alles once again threatened the world—a phoenix arising from its ashes not yet cold.

The German Army of World War II was the end product of nearly a century devoted continuously to the exhaustive study of all aspects of the science of war. It was the product of a totalitarian country which had accepted total war as an instrument of its national policy and which supported the armed forces with every scientific, economic, political, and psychological resource available. The weapons were the best that keen scientific and military minds could devise and which the country's economic resources could provide. The overall weapons system was tailored to fit the new tactical doctrine created and taught by the general staff, a tactical doctrine new in the means by which it would be carried out but employing every ruse and effect which had been known to succeed in wars through the ages. They called this type of warfare the blitzkrieg. The main components of the blitzkrieg included deep penetration on a narrow front by huge armored vehicles and demoralization of the enemy and destruction of his lines of communications by screaming dive bombers. Penetrate, surprise, shock, encircle, demoralize, and mop up—this was the simple theme. The blitzkrieg proved singularly effective in the early days of World War II against troops woefully and inadequately prepared by training and by their equipment to stop such a force.

In this type of warfare, the infantry was more or less relegated to the position of mopping up a confused enemy force cut off from reinforcements and from contact with the rear. If the infantry was used as an initial assault element, the purpose was limited to achieving a penetration or wedge to permit the armor to go through the infantry for the primary phase of the attack. The infantry was also used to follow up the tank assault in order to protect the flanks and to consolidate the ground gained before the phase of general mopping-up operations. Accordingly, many weapons of the infantryman were automatic. While having less accuracy or range than conventional aimed small arms, they better suited the missions of the German infantry. Initially, however, the basic arm of the German infantryman was the carbine, Kar. (Karabiner) 98K, a bolt-action weapon which was just as efficient at long ranges as any other European rifle. At the time of the attack on Soviet Russia, the German infantryman did not have as many automatic weapons as his counterpart in the Red Army.

German artillery doctrine closely resembled that of the U.S. Army, but, in practice, greater emphasis was given to assault guns for close support of the attacking infantry or armor. Less emphasis was given to AA artillery during the earlier periods of the war, since it was expected that the Luftwaffe would have general air superiority over any of the foreseeable enemies of the German Reich.

However, it has always been the fate of new offensive weapons and methods to meet their equal, eventually, in adequate defensive weapons and tactics. As the war progressed, the Germans were to find that armor sent alone against adequate AT defenses soon became "sitting ducks." In tank-versus-tank warfare, the Germans were chagrined to discover that the Soviet Union had developed tanks with sufficient armorplate protection and long-range guns to enable them to hold their own against German tanks. The other Allies had, meanwhile, fielded enough armor and developed tactics which enabled them to "gang up" on German armor. An unforeseeable eventuality to the Nazi war chiefs was the drastic loss in air superiority which the Luftwaffe suffered. The greater strength of the Allies in artillery and in longer range, high-velocity infantry weapons was a great deterrent to the successful employment of the German foot soldier. The period of "blitzkrieging" had come to an end.

To meet these changes, the German Army created units of motorized and armored infantry to be employed with the armor to destroy enemy AT defenses and protect friendly tanks. More artillery was made self-propelled and mounted on armored vehicles to facilitate their deployment and to make Allied counterbattery more difficult, but fuel shortages eventually erased these advantages. Effective AA artillery systems were developed. Antitank and AA weapons were ingeniously used as assault and defensive weapons. Rocket-type artillery, although less accurate than conventional or recoilless types, was created to make up for shortcomings in German artillery, especially in laying massed fires ahead of attacking formations and in the protection of the flanks of attacking columns. The original overdevotion to the principle of providing automatic weapons to the infantry could not be changed for new reasons. Critical manpower shortages hit the Wehrmacht, and it became necessary to cut down the personnel strengths of ground units while at the same time increasing firepower by using even more automatic weapons. Finally, the German concept of an aggressive, mobile, and fluid defense had to be abandoned for linear-type defenses in depth and in strongly fortified, organized positions.

The German Army which had started the war with arrogant confidence in its sensational offensive techniques finished the war with great despair while desperately employing every defensive means possible to forestall the obvious end and in order, perhaps, to obtain a peace short of unconditional surrender.

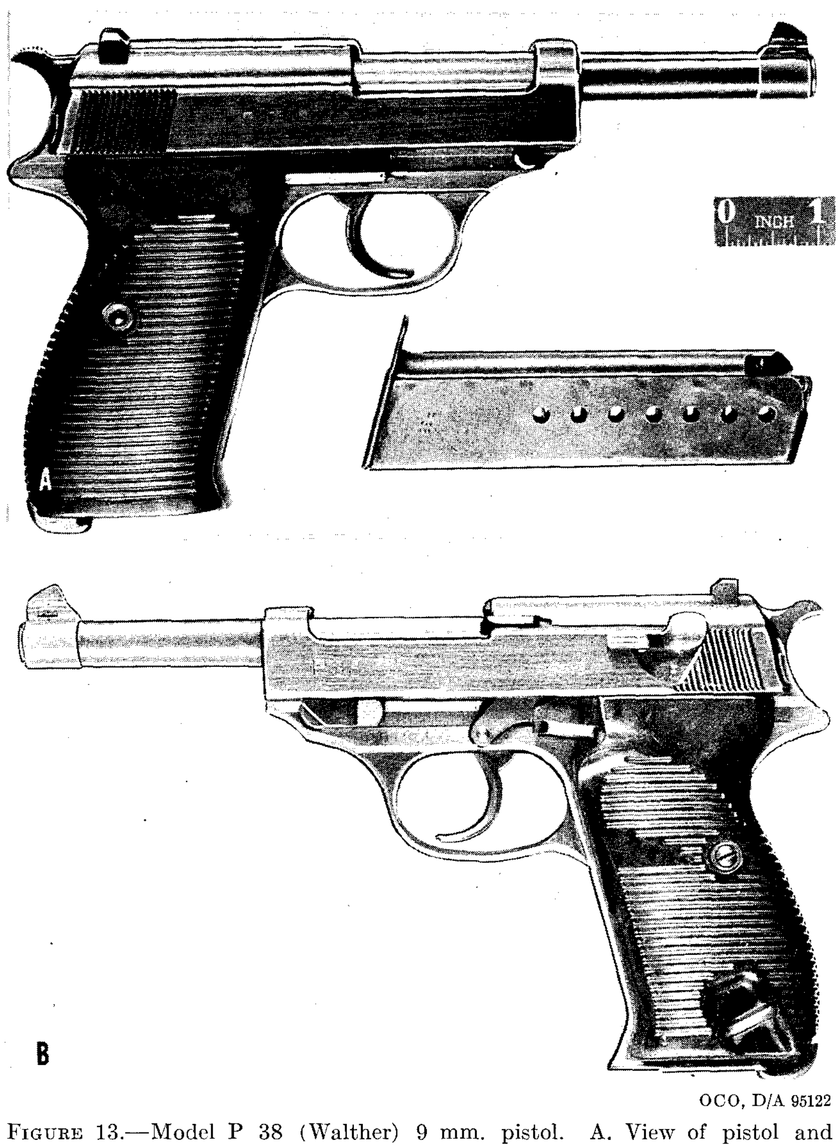
The foregoing summary, it is hoped, will provide the reader with background information to help him better understand and evaluate the descriptions of individual items of German ordnance which follow.

Small Arms

Pistols.—Perhaps the most widely known official sidearm of the German Army was the 9 mm. (0.354 in.) Parabellum pistol or Luger (P (Pistole) 08). The 1908 model was a modification of an original Borchardt pistol which the

Germans had redesigned in 1900 and designated the Luger. This weapon was well recognized for its power and accuracy and customarily utilized an 8-round magazine with 9 mm. Parabellum ball ammunition. Variations in the propelling charge of the cartridge resulted in muzzle velocities ranging from as low as 1,025 to as high as 1,500 f.p.s. The maximum range with lowest powered cartridge was about 1,200 yards, and the effective range was from 50 to 75 yards.

A later issue standard German sidearm was the 9 mm. Walther semiautomatic pistol (P 38) (fig. 13). One of the distinguishing features of this weapon



OCO, D/A 95122

FIGURE 13.—Model P 38 (Walther) 9 mm. pistol. A. View of pistol and magazine. B. View of pistol with magazine inserted.

was its double action, which enabled it to be fired by squeezing the trigger without first cocking the hammer when there was a cartridge in the chamber. The Walther fired the regular issue German 9 mm. Parabellum ammunition and could also use the 9 mm. ammunition manufactured for the British Sten, British Lanchester, and the Italian Beretta submachineguns. Ballistic data were the same as for the Parabellum (Luger) pistol.

Submachineguns.—The 9 mm. MP (Maschinenpistole) 18 was the original German submachinegun introduced toward the end of World War I and continued in limited use—police, concentration camp guards—through World War II. It fired the standard 9 mm. Parabellum ammunition with a 32-round drum magazine. The cyclic rate of fire was 550 rounds per minute; the effective range, 218 yards.

A more recent model of the 9 mm. submachinegun was the Bergmann MP 34. This was a semiautomatic or full-automatic, air-cooled, blowback-operated weapon which was fed by a 32-round box magazine. The effective range was 218 yards; the maximum rate of fire was from 500 to 600 rounds per minute; and the practical rate of fire, 120 rounds per minute. Another 9 mm. submachinegun was originally designed for use by paratroopers but gradually came to be used by all general combat units. It was first brought out as the model MP 38 and later modified as the MP 40 (Schmeisser) (fig. 14). Both models were equipped with a folding shoulder stock and could be used as either a shoulder or a hip weapon. Standard 9 mm. Parabellum ammunition was used with a 32-round box magazine, and both had muzzle velocities of 1,040 to 1,250 f.p.s. The effective range was 200 yards; cyclic rate of fire, from 450 to 600 rounds per minute, depending upon the type of ammunition and the tension of the recoil spring. The practical rate of fire was 180 rounds per minute.

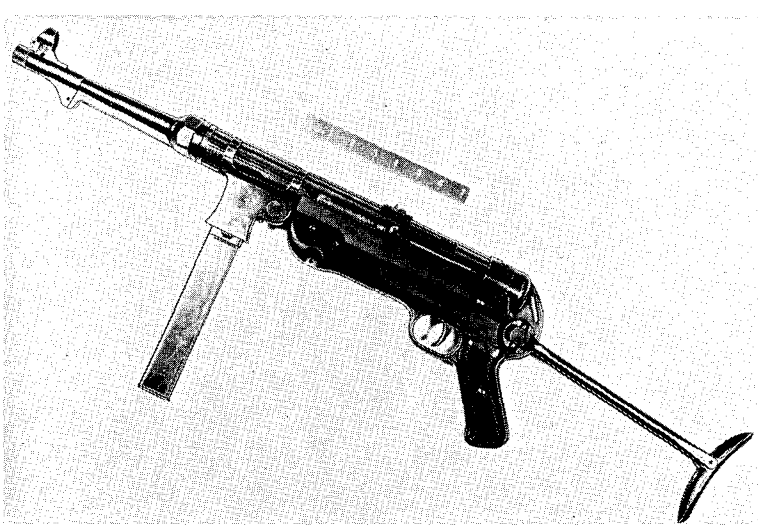


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FIGURE 14.—MP 40 (Schmeisser) 9 mm. submachinegun, stock extended.

When fired fully automatically, however, these weapons could not have been accurate at ranges over 100 yards.

During the course of the war, the Germans issued various models of a 7.92 mm. (0.312 in.) submachinegun. The most commonly encountered models were the MP 43, MP 43/1 and the MP 44. The designation of the MP 44 was later changed to Sturmgewehr 44 (assault rifle 44). The original design from which these weapons were developed was the 7.92 mm. M. Kb. 42 (machine carbine 42). Many parts were constructed from steel stampings, but the gun was very serviceable with reliable operation and general accuracy. The ammunition was 7.92 mm. type MP 43 Patronen with mild steel core and had a muzzle velocity of approximately 2,250 f.p.s. The effective range was 400 yards, with an effective automatic rate of fire of 100 to 120 rounds per minute and a semiautomatic rate of fire of 40 to 50 rounds per minute.

Rifles and carbines.—The standard shoulder weapon of the German Army was a 7.92 mm. carbine, Kar. 98K of Mauser design (fig. 15). It could be

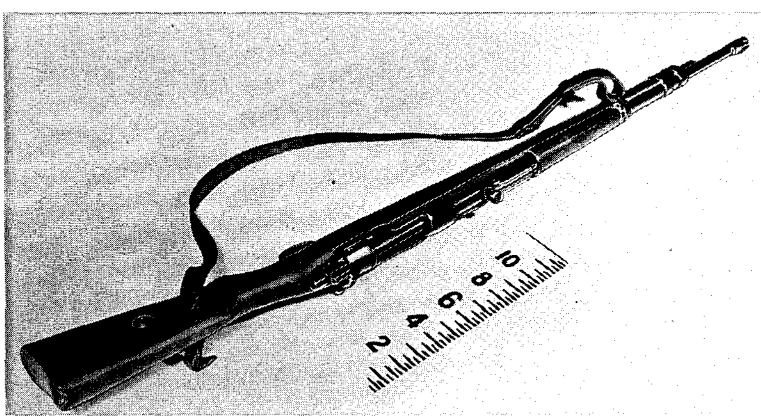

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FIGURE 15.—Model 98, 7.92 mm. German Mauser rifle.

regarded as a carbine or a short rifle. In general design, it was similar to the U.S. M1903 rifle, and certain parts were interchangeable with the later model German carbine, G. (Gewehr) 33/40. The Kar. 98K weighed 9 pounds and had an overall length of 43.5 inches. It fired 7.92 mm. Mauser, ground-type ammunition with a muzzle velocity of 2,600 to 2,800 f.p.s. The maximum range was approximately 2,500 to 3,000 yards with an effective range of approximately 600 to 800 yards.

Three older models of this gun, which varied only in barrel length and other minor design features (the Gewehr 98, the Kar. 98, and the Kar. 98B) were auxiliary and supplementary.

The 7.92 mm. carbine, Gewehr 33/40, was typical of the German carbine design. This gun had an overall length of 39⅛ inches, weighed 7 pounds 11 ounces, and had a manually operated bolt action. The carbine fired 7.92 mm.

Mauser ball-type ammunition. The G. 33/40 was actually the Czech 7.92 Model 33, slightly modified, and manufactured by the Germans at Ceska Zobrovka Brno.

A number of 7.92 mm. semiautomatic rifles were also issued, and these appeared to fulfill the same function as the U.S. .30-caliber rifle, M1. The G. 41 (W) and G. 41 (M) were basically the same, except for minor external changes, different bolt mechanisms, and manufacturing methods. Both rifles were gas operated, air cooled, and fed by a 10-round box magazine. On thorough testing at the Aberdeen Proving Ground in Maryland, the G. 41 (W) proved to be much inferior to the U.S. rifle, caliber .30, M1 in reliability under severe conditions. It fell down especially in mud and rain tests, and breakages were numerous.

In an attempt to reduce the expense and to expedite the manufacture of the semiautomatic rifle, the Germans also produced the 7.92 mm. Kar. 43 which used a maximum number of forgings and stampings in its construction.

The 7.92 mm. German paratroop rifle, FG (Fallschirmjäger Gewehr) 42, (fig. 16), was used by ground troops and was employed either as a submachinegun, a rifle, or as a light machinegun. Its action was a modification of the Lewis light machinegun, and it fired the 7.92 mm. Mauser ground-type ammunition with a cyclic rate of fire of 600 rounds per minute.

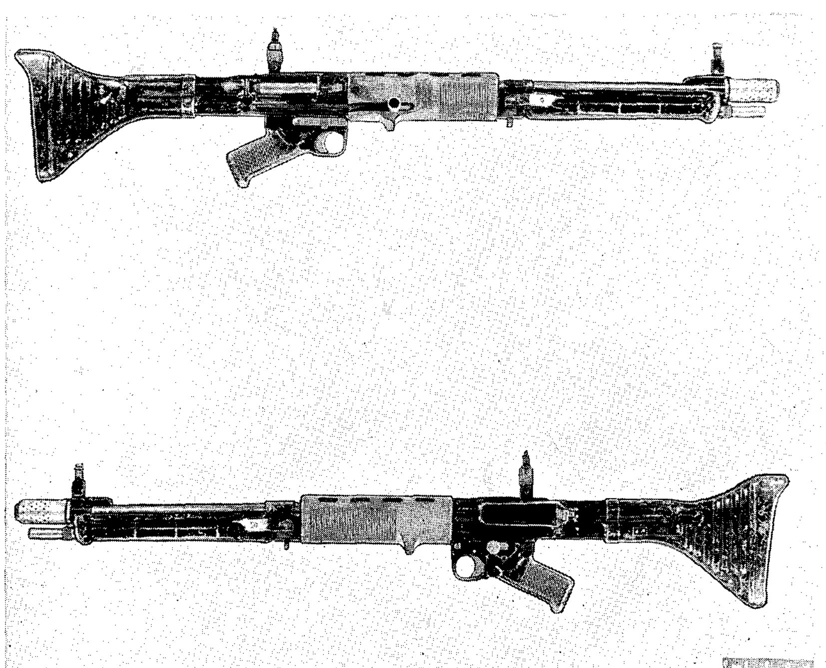

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FIGURE 16.—Model FG 42 (1st version) 7.92 mm. automatic rifle.

During the invasion and occupation of Poland, the Germans captured large numbers of the Mascerzek 7.92 mm. AT rifle, Model 35 (fig. 17). These rifles were issued to the German ground forces and were used extensively in the early stages of World War II. The Polish weapon was a bolt-action gun of the modified Mauser type and resembled the Mauser rifle except that it was longer and heavier and had a muzzle brake. The ammunition, which had a steel jacket with an AP steel core and a lead antimony filler, was contained in a 5-round clip. The muzzle velocity was very high, 4,100 f.p.s.

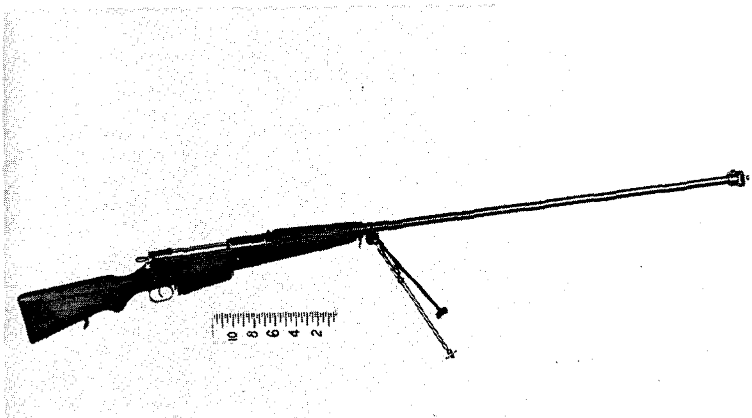

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FIGURE 17.—Model 35 (ex-Polish) 7.92 mm. antitank rifle.

Following the Polish design, the Germans produced several rifles identified as Pz.B (Panzerbüchse) 38 and 39. The Pz.B 39 was manually loaded and fired a single shot from the shoulder with the aid of a bipod. The ammunition was a 13 mm. cartridge case necked down to 7.92 mm., similar to that used in the Polish AT rifle. The projectile had a tungsten carbide core with a lacrimator pellet and tracer mixture. The muzzle velocity was 3,540 f.p.s., with a 1¼-inch penetration of face-hardened plate at a range of 100 yards.

By means of minor design alterations, the Pz.B 39 was modified to a grenade throwing rifle (Granatbüchse 39). The attached launcher was the Scheissbecher which was the same type used on the Mauser Kar. 98K rifle. Both large and small AT grenades and antipersonnel grenades could be fired from the rifle. The propelling medium was a wood-bullet blank cartridge.

Machineguns.—The most commonly encountered automatic weapon used by the German armed forces was the 7.92 mm. dual-purpose machinegun, Model 34 (MG (Maschinengewehr) 34) (fig. 18). This weapon possessed an unusual degree of adaptability since it could be used as a light or heavy machinegun against ground targets and troops or as an AA machinegun. It could also be mounted on tanks and other vehicles. The ammunition consisted of the 7.92 mm. Mauser ground type and was supplied in 75-round saddle-type drums, 50-round belt drums, and nondisintegrating metallic link belts. The

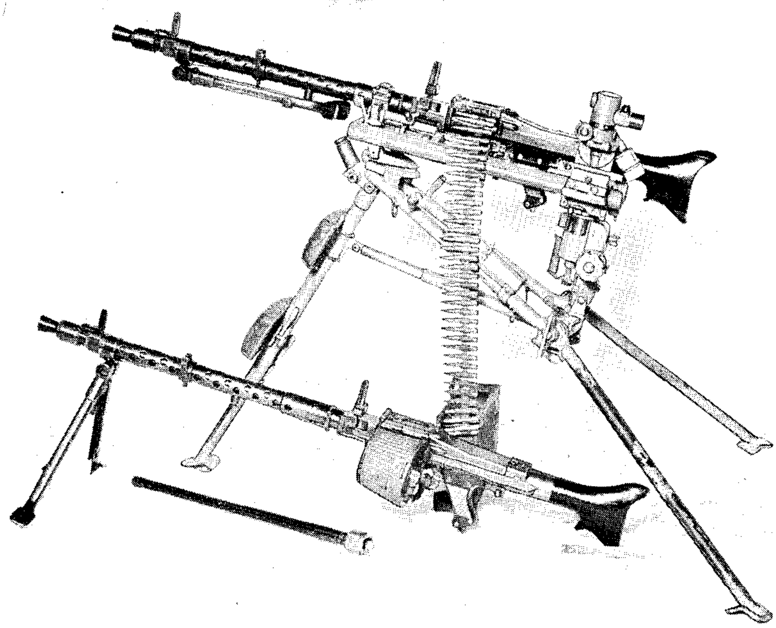

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FIGURE 18.—MG 34 (Solothurn) 7.92 mm. dual-purpose machinegun.

muzzle velocity varied between 2,500 to 3,000 f.p.s., depending upon the type of ammunition. The cyclic rate of fire was from 800 to 900 rounds per minute, and the practical rate of fire as a light machinegun was from 100 to 120 rounds per minute. As a heavy machinegun, this rate increased to 300 to 350 rounds per minute. The maximum range was about 5,000 yards with an effective range as a light machinegun of 600 to 800 yards and as a heavy machinegun of 2,000 to over 3,800 yards.

In the later developments of the MG 34, a number of models were produced (MG 34 modified, MG 34 S, and MG 34/41)—all of them retaining the original pattern of the weapon—but each modification tended toward simplification and elimination of machine parts. One of the latest models of German ground machineguns was the 7.92 mm. MG 42 which was intended to replace the MG 34. The MG 42 continued to be a multipurpose machinegun which could be mounted on a bipod as a light machinegun and on a tripod as a heavy machinegun. The MG 34 and 42 could also be used as AA machineguns and could be mounted on armored vehicles. The feeding device consisted of 50-round links of metallic nondisintegrating link belt or 50-round belt drums. The muzzle velocity was from 2,500 to 3,000 f.p.s., with a cyclic rate of fire of 1,335 rounds per minute. When used as a light machinegun, the maximum range was 2,200 yards and the effective range, from 600 to 800 yards.

After the occupation of Czechoslovakia, the Germans adopted one of the Czechoslovak 7.92 mm. heavy machineguns and labeled it MG 37 (T) (Brno). This weapon appeared to have been designed primarily for use on tanks and other armored vehicles, but it was also very effective as a heavy machinegun when mounted on a tripod.

Although primarily intended as an aircraft machinegun, the 7.92 mm. MG 15 was frequently utilized as a ground weapon by adding a standard bipod and a butt extension. The standard 7.92 mm. rimless ammunition was used in this gun with a cyclic rate of fire of 1,000 rounds per minute and a practical rate of fire of 300 rounds per minute. This gun was produced in Japan as the Model 98 (1938) flexible aircraft machinegun.

Mortars

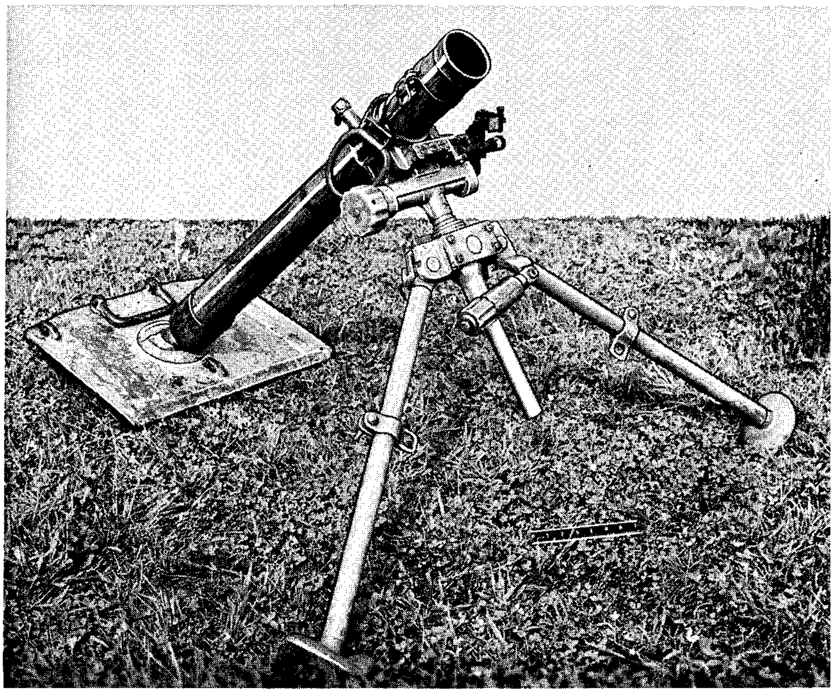
At the onset of World War II, the Germans had two principal mortars, the 50 mm. company and the 81 mm. battalion. When it became apparent that they could not match the firepower of their enemies, especially the Soviet forces, a short 81 mm. mortar was designed to supplement the 50 mm.

The German 50 mm. (1.969 in.) light mortar (5 cm. l.Gr.W. (Leichter Granatenwerfer) 36) consisted of a tube, cradle, and baseplate and differed from the conventional American mortar design in being trigger fired. This weapon had a total weight of 31 pounds, and, owing to its compact structure, it could easily be broken down into two loads for transportation. It fired an HE projectile weighing 2.2 pounds with a muzzle velocity of 230 f.p.s. and a maximum range of 550 yards at 45° elevation. The rate of fire was from 12 to 20 rounds per minute.

A power-operated automatic 50 mm. mortar (5 cm. Machinengranatwerfer) was found in special concrete turrets in fixed defensive systems. This weapon was almost twice as long as the standard 50 mm. mortar. A 6-round clip was manually loaded into a rack, and as each round was fed into the breechblock the tube would slide down over the shell and lock into place. The feeding, locking, and firing mechanisms were electrically operated.

The German 81 mm. (3.19 in.) mortar (8 cm. s.Gr.W. (Schwerer Granatenwerfer) 34) (fig. 19) was the equivalent of the U.S. 81 mm. mortar, M1. This weapon was a smoothbore, muzzle-loaded mortar with a fixed firing pin and weighed 124 pounds. Standard smoke and HE ammunition were used. The HE shell weighed 7.7 pounds and had a maximum range varying between 1,094 and 2,625 yards, depending upon the number of propellent increments. In addition, a modified HE shell known as the "bouncing bomb" was developed to provide an airburst, but it proved unsuccessful.

In an attempt to combine the firepower of a medium mortar with the mobility and lighter weight of a light mortar, the Germans produced a short 81 mm. mortar (8 cm. Kz. Gr.W. (Kurzer Granatenwerfer) 42). This weapon, with a shorter barrel and smaller baseplate and bipod than the standard 81 mm.



OCO, D/A 69245

FIGURE 19.—81 mm. mortar with bipod and baseplate.

mortar, weighed 62 pounds and fired the HE shell with a maximum range of 1,200 yards.

Among the heavy mortars, the 105 mm. (4.13 in.) smoke mortar (10 cm. Nebelwerfer 35) was an enlarged version of the standard 81 mm. mortar and corresponded to the U.S. 4.2-inch chemical mortar. Although it was issued originally to chemical warfare troops for firing smoke and chemical shells, a 16-pound HE shell with a maximum range of 3,300 yards was also issued. Another 105 mm. chemical mortar (10 cm. Nebelwerfer 40) was a smoothbore, breechloaded weapon transported on a carriage from which it could be fired. This mortar fired an HE shell weighing 19.1 pounds and had a maximum range of 6,780 yards.

After the invasion of the U.S.S.R. and the capture of large numbers of the Soviet 120 mm. (4.7 in.) mortar (fig. 36), the Germans adopted this weapon and began to manufacture it in Germany. This mortar (12 cm. Gr.W. 42) was conventional in design and had a total weight in the firing position of 616 pounds and a barrel length of 6.12 feet. The German model could be percussion or trigger fired and used four types of German HE shells as well as captured Soviet ammunition. The HE ammunition weighed 35 pounds and, with a maximum range of 6,600 yards, provided artillery support comparable with

that from the 105 mm. field howitzer. Because of its high degree of mobility, it could quickly be towed or manhandled into a new firing position. This was accomplished by means of an easily attached two-wheeled carriage and by having the bipod carried clamped to the mortar ready for action. This same mortar was destined to be used again in Korea against American troops.

A 200 mm. (7.87 in.) spigot mortar (20 cm. Leichter Ladungswerfer) was developed for use by engineering units in the destruction of minefields, concrete fieldworks, and wire obstructions. It fired a standard HE shell that weighed 46 pounds and had a maximum range of 776 yards. A 380 mm. heavy spigot mortar with an HE shell weighing 331 pounds was probably an enlarged version of the 200 mm. weapon.

Artillery, Guns, and Howitzers

As in the case of Japanese ordnance, the variety of German guns and howitzers defies a description of each. Moreover, the details of the construction and functioning of any of these pieces would not contribute materially to an understanding of their casualty-producing capabilities. In view of these considerations, table 8 lists the primary conventional artillery pieces of the German Army and shows the type, caliber, ammunition used, projectile weights, and maximum range. The models with a designation of "18" signify those which constituted the standard artillery of the German Army when it entered World War II. Some of these were originally developed in World War I. In addition to the guns and howitzers shown in table 8, there were many models of heavy artillery—mostly long-range guns—which ranged in size from 21 cm. (8.27 in.) to 80 cm. (31.5 in.). These will not be described because they were not intended to be casualty producing in frontline areas and are not significant in the casualty surveys which make up some of the later chapters of this volume.

While AT (fig. 20) and AA weapons do not normally function as primary casualty-producing instruments of war against ground troops, they must be considered here because of the widespread use by the Germans of their 8.8 cm. (88 mm.) HE shell against ground formations. In almost all cases, German 8.8 cm. guns were either AA or AT weapons.

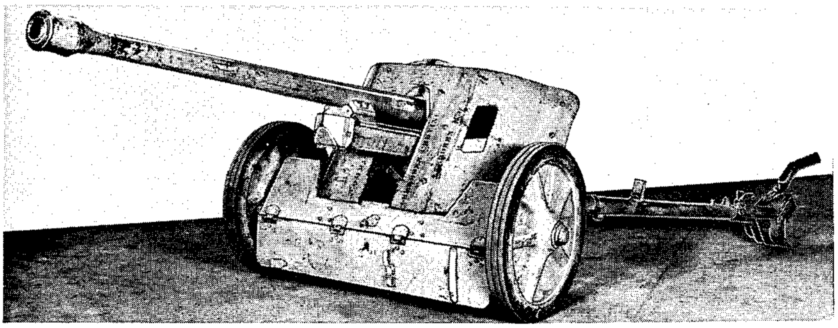


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FIGURE 20.—Pak 38, 50 mm. antitank gun.

The basic 8.8 cm. gun was the Flak 18 which appeared as early as 1934 as the standard AA artillery of the German Army. Later models were the Flak 36 and 37 which differed only in mounts and data-transmission systems. Characteristic of AA artillery, these guns had an extremely long tube of 15 feet 5 inches. The maximum horizontal range was 16,200 yards with the 20-pound HE round. The muzzle velocity with the HE shell was 2,690 f.p.s. Standing on its AA platform, these models could traverse a complete 360°, be deflected 3° below the horizontal, and elevated 85° above the horizontal.

The Flak 36 gun also appeared as the standard armament of the heavy Tiger tanks. These tanks were designed primarily for defensive warfare or for breaking through strong lines of defense and were relatively slow and cumbersome—stark evidence of the German turnabout from the blitzkrieg theory. Because of the huge gun—it extended 8 feet 10 inches beyond the forward end of the King Tiger tank—the hulls of the Tiger tanks were of interlocked welded steel, and their turrets were constructed in one piece in order to give sufficient rigidity. The King Tiger was virtually invulnerable to frontal attack.

The 8.8 cm. Flak 41 was basically similar in design to the Flak 18, 36, and 37 but was larger all around, platform mounted on a highly mobile wheeled base, and designed specifically as a multipurpose gun—AA, AT, and antipersonnel. The 21-foot 5.75-inch tube increased the muzzle velocity to 3,280 f.p.s., with an accompanying increase in maximum horizontal range to 21,580 yards. An automatic rammer and electrical firing mechanism allowed a practical rate of fire of 20 rounds per minute. By a special device incorporated in the platform, it could be fired from its wheels.

The 8.8 cm. gun also appeared in several models of the 8.8 cm. Pak 43 (fig. 21) which were mounted in tank destroyers and in the Jagdpanther, a self-propelled gun on the Panther heavy tank chassis. The tank destroyers

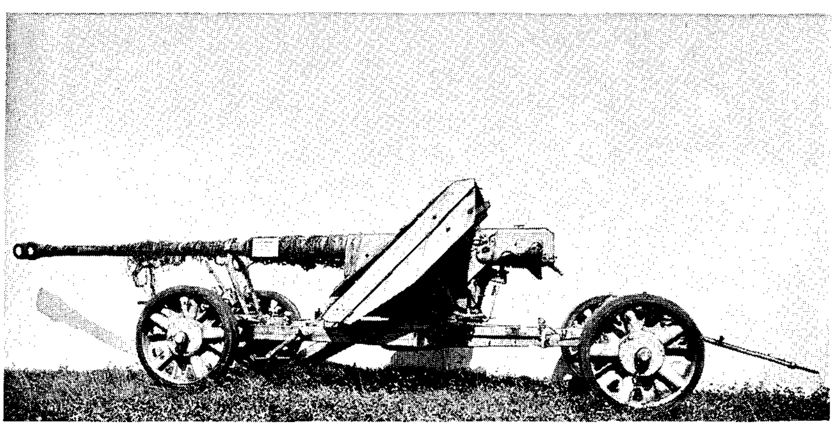

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FIGURE 21.—Pak 43, 8.8 cm. antitank gun.

TABLE 8.—*German guns and howitzers*

Weapon	Type	Caliber: Centimeters	Caliber: Inches	Projectile: Type	Projectile: Weight	Projectile: Muzzle velocity	Projectile: Maximum range
					Pounds	*F.p.s.*	*Yards*
Gebirgs Kanone 15	Mountain howitzer	7. 5	2. 95	HE, hollow charge, shrapnel, and AP.	12 HE	1, 270	7, 270.
le. I.G. 18 [1]	Light infantry gun	7. 5	2. 95	HE and hollow charge.	12.13 and 13.2 (HE).	730	3,900.
Geb. G. 36 [2]	Light mountain howitzer.	7. 5	2. 95	do	12.6 and 12.81 (HE).	1,558	10,100.
le. I.G. 37	Infantry gun	7. 5	2. 95	do	12.13 and 13.2 (HE).	1,165	5,630.
le. F.K. 18	Light field gun	7. 5	2. 95	HE and shrapnel	Undetermined	1,558	10,935.
Feldkanone 38	Field gun	7. 5	2. 95	HE and hollow charge.	12.85 and 13.88 (HE).	1,985	12,570.
Feldkanone 36 (r) [3]	do	7. 62	3. 0	HE, APHE, AP	13.45 (HE)	2,335	14,000 (APHE).
Flak 18, 36, 37, and 41.[4]	Multipurpose gun	8. 8	3. 46	HE and AP	20.35 (HE)	2,690	16,183.
le. F.K. 18[5]	Field gun	10. 5	4. 14	HE, AP, APCBC	33.5 (HE)	2,740	20,850.
Leichte Feld Haubitze 18. [6]	Field howitzer	10. 5	4. 14	HE, AP, APHE, hollow charge, chemical, smoke incendiary.	32.6 (HE)	1,772 (le. F.H. 18/40).	13,480 (le. F.H. 18/40).
le. F.H. 18(M)[4]	do	10. 5	4. 14	do	32.7 (HE)	1,772	13,500.
le. F.H. 18/40 [4]	do	10. 5	4. 14	do	32.6 (HE)	1,772	13,479.
Geb. H. 40 [7]	Mountain howitzer	10. 5	4. 14	HE hollow charge, smoke.	32. 6 (HE)	1,870	13,810.
Kanone 44	Medium field gun	12. 8	5. 04	HE, AP			
s.F.H. 18 [8]	Medium howitzer	15	5. 91	HE, AP, anticoncrete, smoke.	95.7 (HE)	1,705	14,630.
s.I.G. 33 [9]	Heavy infantry gun	15	5. 91	HE smoke, stick bomb.	84 (HE) 97 (Stick).	787	5,140 (HE).

Kanone 18[10]	Medium field gun	15	5. 91	HE, AP, anticoncrete.	94.6 (HE)	2,838	27,040.
Kanone 39[4]	do	15	5. 91	do	94.6 (HE)	2,838	27,040.
s.F.K. 16[4]	Heavy field gun	15	5. 91	HE capped	113	2,480	21,370.
17 cm. K. mit Mrs. Laf. 18.[11]	Long range mobile gun.	17	6. 79	HE, HEBC, AP	138 (HE)	3,035	32,370.
21 cm. mit Mrs. Laf. 18.[12]	Heavy howitzer	21	8. 27	HE, anticoncrete	249 (HE)	1,854	18,300.

[1] Close support weapon capable of both low- and high-angle fire.
[2] Standard light mountain howitzer.
[3] Of Soviet design and manufacture.
[4] See text, p. 47 for various uses.
[5] Standard medium gun.
[6] Standard divisional field howitzer developed in World War I. Modified 1941 and called le. F.H. 18(M); 1944, le. F.H. 18/40. All ballistically identical; later models increased range.
[7] Latest mountain artillery.
[8] Standard divisional artillery medium howitzer. Later modifications included s.F.H. 18/40 and s.F.H. 42; modified models had muzzle velocity of 1,952 f.p.s. and maximum range of 16,514 yards.
[9] Standard infantry gun capable of both low- and high-angle fire.
[10] The 15 cm. K39 was a later modification with similar ballistic characteristics and which could be mounted on an emplaced platform as a coast defense gun.
[11] This gun could be put into and taken out of action very rapidly. Mounted in the 21 cm. Mörserlafette 18 carriage.
[12] Standard heavy howitzer.

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carried from 20 to 70 rounds of HE ammunition in addition to the AP types. The muzzle velocity was 2,400 f.p.s., with a 20.7-pound HE round. While these tank destroyers were primarily designed to fight enemy tanks at long range, they and the Jagdpanther could be used for many other purposes where a highly mobile, rapid-firing gun with plenty of power was required.

Artillery, Recoilless Weapons, and Rocket Launchers

With the use of a funneled tube (venturi) attached to the rear of the bored breechblock to allow the gases to escape to the rear, the heavy recoil and counterrecoil systems of artillery weapons can be eliminated. The result is a lighter recoilless weapon. Therefore, most of the German recoilless weapons were originally designated for use in airborne operations, but they also saw extensive use in general ground combat.

The German recoilless 44 mm. AT grenade launchers (Panzerfaust) can hardly be classified as artillery weapons, since the entire launcher tube was handled by the individual soldier. The Panzerfaust Klein 30 was an even smaller version. Four models which varied only in overall size and weight of the tube and in the sighting rail were produced.

There was also an 8.8 cm. rocket launcher which was very similar to the U.S. 2.36-inch rocket launcher (Bazooka) and a heavy 8.8 cm. rocket launcher mounted on a two-wheeled carriage with single trail. The latter more nearly approached the proportions of recoilless artillery, but it did not have traversing or elevating mechanisms characteristic of artillery pieces.

German recoilless artillery weapons were 7.5 cm. or 10.5 cm. in caliber and designed to break down into loads for pack or airborne artillery. The 75 mm. (2.95 in.) airborne recoilless gun (7.5 cm. L.G. 40) had its weight, 325 pounds, reduced to a minimum so that it could be dropped by parachute in two wicker containers. In comparison, the standard German 75 mm. light mountain howitzer weighed 1,650 pounds. The HE ammunition weighed 12 pounds, and this recoilless weapon had a muzzle velocity of 1,238 f.p.s., with an estimated maximum range of 8,900 yards. In addition, hollow-charge and AP projectiles were available for AT purposes.

There were two types of the 10.5 cm. (4.14 in.) airborne recoilless gun employed by the German Army. The 10.5 cm. L. G. 40 was the earlier model and appeared to be the type most frequently encountered. The tube and venturi jet made the overall length 6 feet 3 inches, and the gun in action weighed 855 pounds. Both HE and hollow-charge projectiles could be fired. Armed with the HE shell which weighed 32.6 pounds, the gun had a muzzle velocity of 1,099 f.p.s. and a maximum range of 8,694 yards. A modification of the L. G. 40 was introduced in 1943 and designated the 10.5 cm. L. G. 42. Modifications in the carriage design, elevating mechanism, and breechblock increased the weight of the gun to 1,217 pounds, but it could still be broken down into five loads for use as pack or airborne artillery. With all these recoilless weapons, the discharge of the propellent gases through the venturi

tube created a danger zone approximately 20 yards wide and 50 yards long to the sides and rear of the gun.

German rocket-type weapons appeared in combat in 1941, and, during the ensuing war years, a considerable number of models were developed and standardized. Some of specialized design were encountered during their experimental trial. Rocket projectors were far more mobile than standard field artillery and were more effective for diffuse smoke and massed HE shellfire over a target area. They did not possess the same degree of accuracy as the more conventional artillery piece. The main use of rocket projectiles was against fortified positions and troop concentrations.

The original tube-type rocket projector was the 15 cm. Nebelwerfer 41 which consisted of a six-barrel assembly mounted on a two-wheeled carriage. It took the crew approximately 90 seconds to fire the six rockets which could be HE or smoke. The HE round weighed 75.3 pounds with which the range of the weapon was 7,330 yards. This type of tube was mounted in two banks of five tubes each on a halftrack and was called the 15 cm. Panzerwerfer 42. The 21 cm. Nebelwerfer 42 was similar in design to the 15 cm. Nebelwerfer 41 and could be adapted with detachable rails to fire the 15 cm. ammunition. The 248-pound HE round gave this weapon a maximum range of 8,600 yards.

An entirely different type of launcher utilized steel or wood frames from which rockets were fired. The first of this type was the wood-frame 28/32 cm. Schweres Wurfgerat 40. Both 28 cm. HE and 32 cm. incendiary rockets could be fired with a maximum range of 2,100 yards in the case of the 184.5-pound, nearly 4-feet-long, HE rocket. The Schweres Wurfgerat 41 was a steel-rack version, and the Schweres Wurfrahmen used the wood Schweres Wurfgerat 40 racks on an armored halftrack. A mobile version of the Schweres Wurfgerat 41 was the 28/32 cm. Nebelwerfer 41 which mounted six racks on a two-wheeled trailer.

The largest of the rocket weapons was the six-frame 30 cm. Nebelwerfer 42. This frame-type launcher used a 30 cm. HE round with a bursting charge of 100 pounds of amatol as compared to the total weight of 75.3 pounds for the 15 cm. rocket and a bursting charge of 28 pounds for the 21 cm. rocket. The range of this 30 cm. rocket weapon was 5,000 yards.

Ammunition

For small arms.—The two principal calibers of small arms ammunition which the Germans used in World War II were 9 mm. and 7.92 mm. In the 9 mm. class, used mainly in pistols and submachineguns, the PPO8 or Parabellum cartridge outnumbered all the other varieties in the field combined. In fact, the Parabellum (or Luger) was probably the most widely used and most efficient military pistol cartridge in the world.

The true pistol cartridge had a brass case and gilding metal or gilding-metal-plated bullet, but this varied according to scarcity of desirable metals,

As substitutes, cases of steel with a copper wash or steel blackened with a protecting lacquer were used. Bullets were made with copper and nickel-alloy jackets, pure nickel jackets, and with gilding-metal-plated steel jackets.

The PPO8 m.E. (mit Eisenkern, with iron core) replaced the standard PPO8 in 1943 and had a steel case, steel-jacketed bullet with mild steel core, and copper-plated jacket inside and out. The bullet weighed only 98 grains as compared with the standard's 124. There was also a 9 mm. sintered iron bullet, PPO8SE.

Two other German 9 mm. cartridges were the M/34 Austrian (Steyer), a 127-grain bullet with considerably more power than the Parabellum, and the 9 mm. Kurz, or "short" (equivalent to the .308 automatic bullet). A third bullet used to some extent by the Germans was the 9 mm. Mauser.

In the 7.92 mm. group, the Germans had many versions, and they never stopped development of different variations until the war was officially over. The bullet lengths varied a great deal through the different types, but all were loaded to an overall length of 80.5 mm. The standard ball bullet was long, boattailed, and very well made (fig. 22). It was lead filled, had a gilding-metal-plated jacket, and weighed about 197 grains. Muzzle velocity varied between 2,400 and 2,500 f.p.s., depending on the weapon in which fired. The Germans had started using steel cases in World War I, and by the end of 1943, most German ammunition had that type of case.

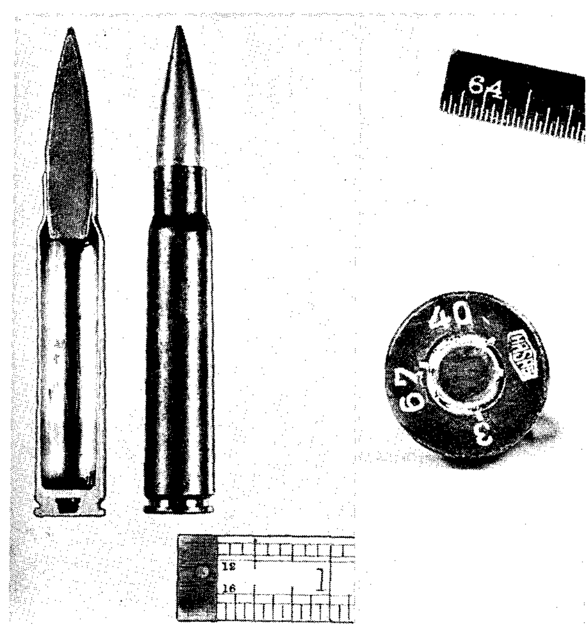

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FIGURE 22.—7.92 mm. German ball ammunition.

German tracer bullets were the best put out by any country—beautifully streamlined and with excellent ballistics. German armor piercers were also very good, being very stable and accurate at long ranges. The commonest type of armor piercer had a hardened-steel core with plated-steel jacket and weighed 178 grains. Other types appeared which used tungsten carbide and combinations for cores. Sintered iron and mild steel cores also came into use in ball ammunition.

The HE incendiary, called the observation bullet by the Germans, had a pellet in it which exploded on contact with any target, however frail. The Germans maintained that it was used mainly for observation and range-finding, but observers report having seen them in rifle clips and machinegun belts.

The two main types of 7.92 mm. HEAT rifle cartridges were the Patr. (Patronen) 318 S.m.K. (Spitzgeschoss mit Stahlkern, pointed bullet with steel core) and the Patr. 318 Polish. The first was an original German type, while the second was a Polish model adopted by the Germans. Muzzle velocity for the German type was given as 3,550 f.p.s., and that for the Polish one a little lower in the weapons for which they were intended.

Table 9 lists the principal types of small arms ammunition along with the guns in which they were used.

For mortars.—As in the case of Japanese mortar ammunition, information available for German mortar ammunition was negligible. The reader is asked to take the descriptions of the German 5 cm. and 8 cm. mortar shells and compare and consider them along with descriptions of Japanese mortar ammunition (p. 22). In this way, perhaps, he may obtain a better picture of the fragmentation and wounding potential of German mortar shells.

Two 5 cm. (50 mm.) HE German mortar shells were tested in 1943 (fig. 23). Each shell, without explosive filler, weighed 1.57 pounds. The 284 fragments recovered from one shell weighed 0.98 pounds, thus representing a 62.4 percent recovery of fragments. For the other shell, 272 fragments were recovered. The fragments weighed 1.13 pounds and represented a 71.9 percent recovery. These data show that there were some 270 fragments per pound of original metal, a proportion roughly twice as large as that for the Japanese 81 mm. mortar shell (p. 22). It should be noted, however, that the many factors which cause variances in experiments of this nature make these comparisons extremely crude.

The 8 cm. (81 mm.) mortar shell incorporated the German attempt to obtain an airburst. It was no reflection of endearment, but, in all probability, familiarity which led the American soldier to call it "Bouncing Betty." This HE shell was quite conventional in design except for a cast nosecap which was secured to the projectile body by four shearpins. Upon impact, a nondelay fuze in the cap ignited a smokeless powder charge. The resulting explosion sheared the pins holding the cap to the body and threw the shell from 5 to 10 feet into the air. In the meantime, a delay pellet was ignited, which in turn ignited a booster charge that detonated the main TNT explosive charge at

TABLE 9.—*German small arms ammunition*

Caliber		German abbreviation	Type	Weapons in which used
Mm.	*Inches*			
9	0.354	Pist. Patr.[1] 08	Pistol, ball	Pistole 08 (Luger); Pistole 38 (Walther); MP 34, MP 40; MP 38; Bergmann and Solothurn submachineguns.
9	.354	Pist. Patr. 08 S.m.E.	Pistol, semi-armor-piercing	Do.
7.92	.312	Patr. s.S. (i.L.) clipped, (o.L.) not in clips.	Heavy pointed ball	Mauser Gew. 98; Kar. 98 K; Kar. 98 B; Kar. 98; MG 34; MG 42; and 7.92 mm. aircraft machineguns.
7.92	.312	Patr. S.m.K.	AP	Mauser Gew. 98; Kar. 98 K; Kar. 98 B; Kar. 98; FG 42; MG 34; MG 42; and 7.92 mm. aircraft machineguns.
7.92	.312	Patr. S.m.K. L'Spur	AP tracer	Do.
7.92	.312	Patr. S.m.K. (H)	Super-armor-piercing with tungsten carbide core.	Do.
7.92	.312	Patr. l.S.	Light ball, special practice	Mauser Gew. 98; Kar. 98 K; Kar. 98 B; Kar 98; MG 34; MG 42; and 7.92 mm. aircraft machineguns.
7.92	.312	Patr. S.m.E.	Mild steel ball	Mauser Gew. 98; Kar. 98 K; Kar. 98 B; Kar 98; FG 42; MG 34; MG 42; and 7.92 mm. aircraft machineguns.
7.92	.312	Patr. S.m.K.	AP incendiary	Do.
7.92	.312	B. Patr.	Incendiary explosive	Do.
7.92	.312	Patr. 318 or Patr. S. S.m.K. (HRs.) L'Spur.	AP tracer with tear gas	PzB. 38 and PzB. 39 AT rifles only.
7.92	.312	Patr. 318 (P)	AP	Polish Mascerzek, Model 35, AT rifle only (bolt-operated shot magazine weapon).

[1]Patr.: Patronen (cartridge).

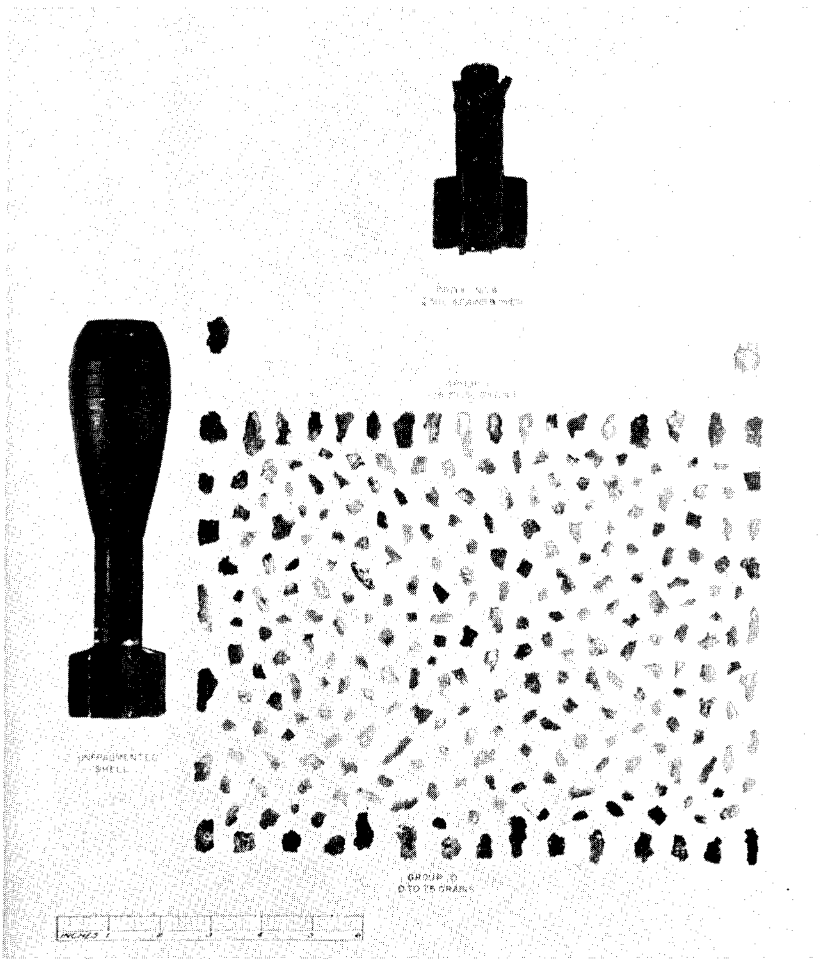

FIGURE 23.—Fragments recovered from one of two 5 cm. high explosive mortar shells detonated under test conditions in the Zone of Interior in 1943.

the approximate peak height of the bounce. This ingenious device produced an airburst without the use of a precision time fuze. It was not as effective or reliable as the time fuze but, on the other hand, neither did the Allies have a mortar shell which was equipped for bursting in midair.

The standard 8 cm. HE mortar shell filled with TNT weighed 3.5 kg. (7¼ lb.). It was 12.95 inches in overall length, and the diameter was 3.16 inches. The mean wall thickness was approximately 0.33 inches. The metal used in the body of the shell was a high quality casting of low carbon cast iron.

Given certain basic facts on any particular shell—type of metal, total weight, diameter and thickness of the shell wall, type of powder and density of filling, outward velocity of shell wall at time of detonation, and the like—such factors as the distribution of fragments by size, velocity of fragments of

various sizes, and retardation of velocity of fragments with distance can be reliably *estimated.* These factors, or variables, can be *extrapolated* for their entire range when even limited empirical data are available.

Using such techniques and given certain data from static fragmentation tests, some characteristics of the German 8 cm. mortar shell were derived of considerable interest. The conclusions are presented in figure 24. The only

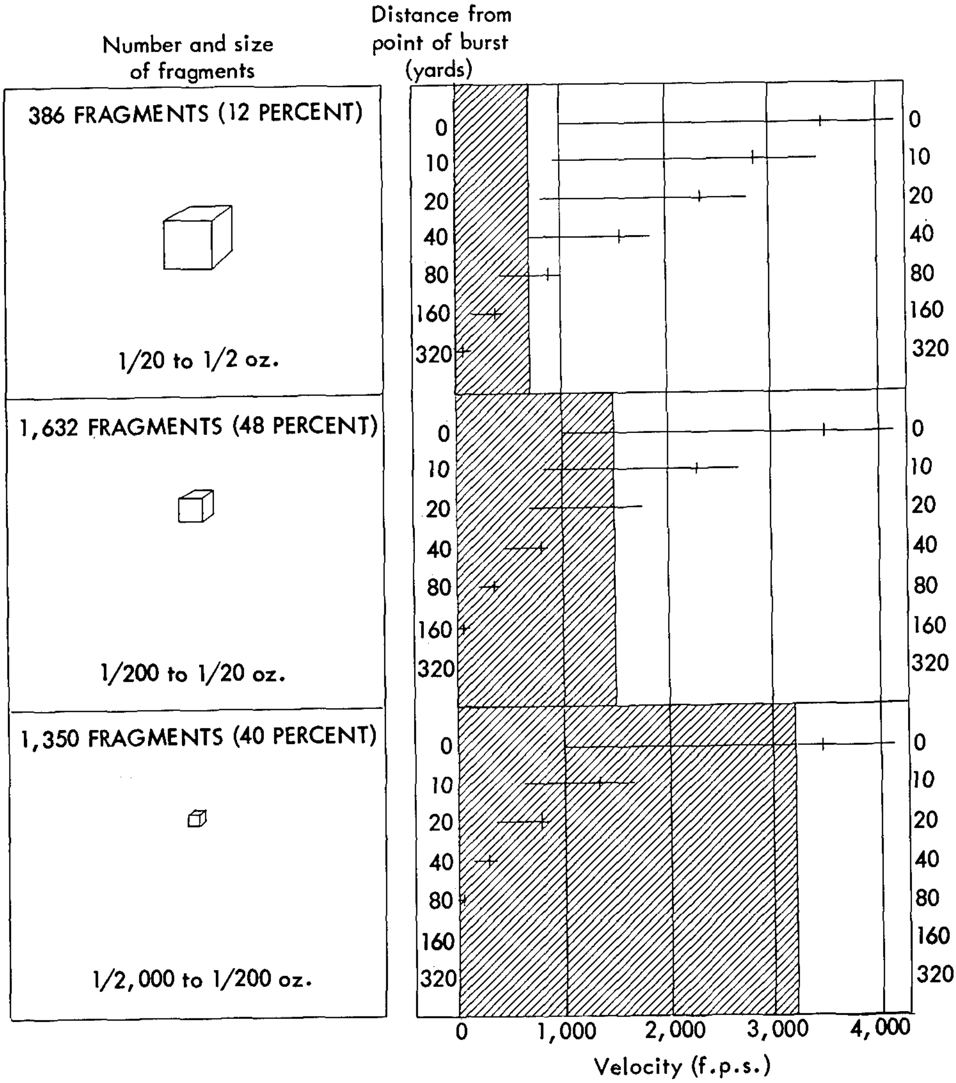

FIGURE 24.—Fragmentation characteristics, German 8 cm. mortar shell. The horizontal lines for velocity give expected ranges of velocities and the vertical intersecting lines give the most probable velocities. The shaded portions show velocities below the incapacitation criterion.

basic assumption required was that the minimum velocity of fragments was 1,000 f.p.s., a very conservative assumption. The criterion for incapacitation (roughly equivalent to hospitalization) was the ability of fragments to penetrate 1 inch of wood. The cubes representing fragment size were obtained by taking the geometrical mean of the class and, as illustrated, show proper relative sizes; absolute size is shown only in scale. Of course, the shape of fragments is generally not cubical, although one dimension must be limited to wall thickness (0.33 in., in this case) and the second dimension in larger fragments is usually found to equal wall thickness. Thus, in the larger fragments, variance in size is often limited to the dimension of length. Finally, it should be observed that, while some fragments were of insufficient mass and velocity to meet the criterion of incapacitation, these could incapacitate, although there is a good chance that they will not.

Many armies of the world were, eventually, to feel the burst of Soviet 120 mm. HE mortar shells—or their imitations—and the German Army was one of them. Germany retaliated against the Red Army, however, by manufacturing, herself, the Soviet-type 120 mm. mortar and shell. Figure 25 shows both the Soviet and German shells. Figures 42 and 43 show the Chinese Communist versions.

Gross dimensions and characteristics of other German mortar ammunition are presented in table 10.

For artillery.—General characteristics of German artillery ammunition commonly used during World War II are presented in table 11. Scattered references to fragmentation characteristics of German artillery ammunition used during World War II were available and are reviewed. While the information is still meager, there is, fortunately, some variety.

Two 50 mm. HE shells for German AT guns were detonated by U.S. Army ordnance personnel. While the specific model of the shells tested was not identified, the weights, empty, of the two specific rounds tested were 3.52 and 3.54 pounds. A total of 202 fragments weighing 3.29 pounds was recovered from one shell, and 193 fragments weighing 3.46 pounds were recovered from the second (fig. 26). This made the percent of fragments recovered 93.4 and 98.3 percent, respectively. Taking, arbitrarily, a ratio of 200 fragments for 3.35 pounds of metal, the number of fragments for 1 pound of metal, a rough measure which was previously adopted for comparative purposes, becomes 60 in this case. It must be noted in this and the other examples for which this rough approximation was calculated that, in all probability, the unrecovered portions represent large numbers of extremely small fragments which would greatly increase the total number of fragments if they could have been recovered and counted. On the other hand, it was previously shown that these minute fragments have considerably less wounding potential. If, as was stated, one dimension of shell fragments is usually a function of the thickness of the shell wall, then many of these extremely small pieces must be sliver shaped. They might not incapacitate a soldier immediately, but it is obvious that they could

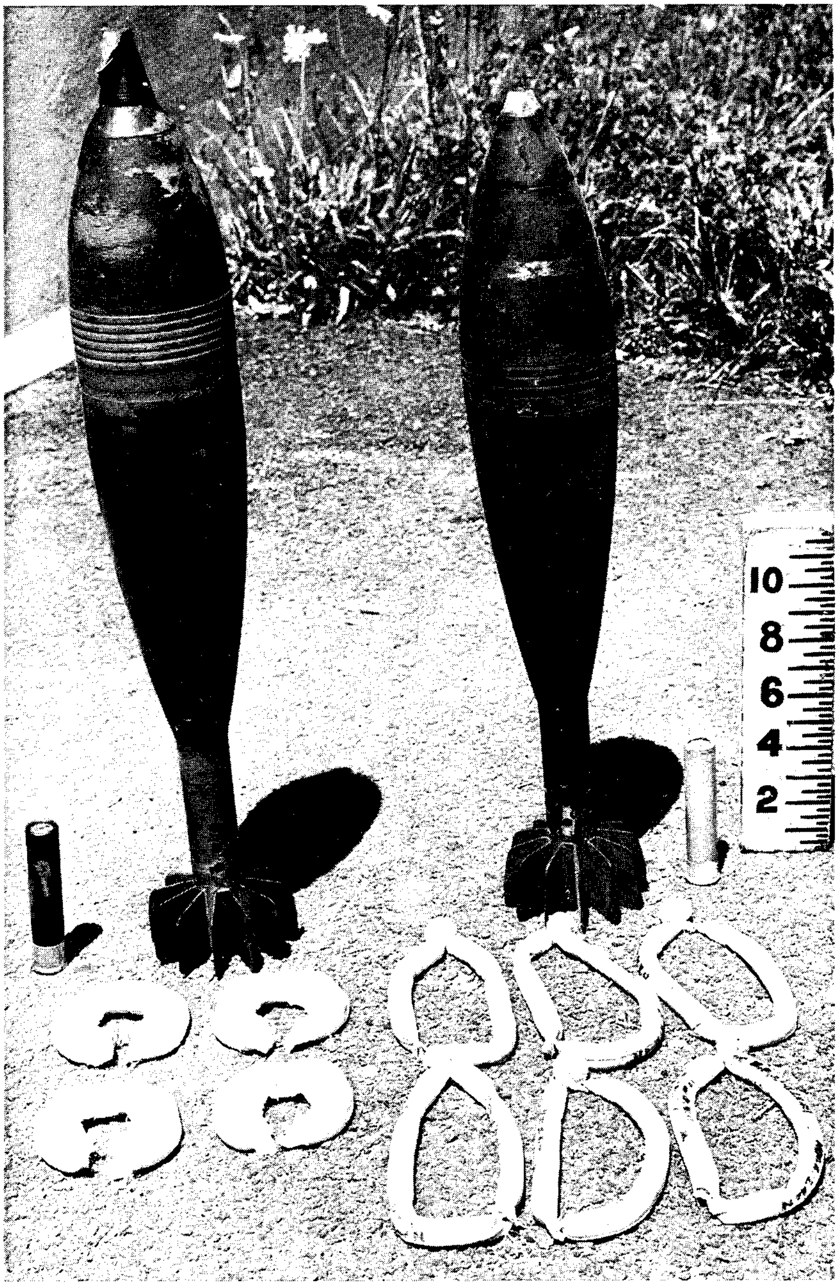

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FIGURE 25.—High explosive mortar shells. (Left) Soviet 120 mm. mortar shell with point-detonating fuze, showing four propelling charges and ignition cartridge. (Right) German version of the Soviet 120 mm. mortar shell with point-detonating fuze, showing six propelling charges.

TABLE 10.—*German mortar ammunition*

Nomenclature	Caliber	Overall length	Explosive component	Weight of ammunition	Fuze	Weapons in which used
	Cm.	*Inches*		*Pounds*		
High explosive bomb	5	8. 625	TNT	2. 2	Wgr.Z. 38	5 cm. 1. Gr. W. 36.
Wurfgranate 38 [1]	8	12. 99	Unidentified	7. 75	Wgr.Z. 38 or 34	8 cm. s. Gr. W. 34.
Wurfgranate 39 [2]	8	13. 109	do	7. 75	do	Do.
Wurfgranate 34 Nebel [3]	8	12. 937	Penthrite wax	7. 85	do	M. Gr. W. 34; Kz. Gr. W. 42.
Wurfgranate 34	8	13. 070	Unidentified	7. 75	do	Kz. Gr. W. 42; 8 cm. s. Gr. W. 34.
Wurfgranate 37	10	17. 12	TNT	16. 0	Wgr.Z. 38	10 cm. Nebelwerfer 35.
Wurfgranate 40	20	30. 86	do	49. 94	Wgr.Z. 36	20 cm. 1. Ladungswerfer.
Wurfgranate 40	38	59. 21	Unidentified	327. 8	do	38 cm. s. Ladungswerfer.

[1] Contains a powder pellet under fuze to give delay action.
[2] An improved model of 38.
[3] A sulfur trioxide smoke shell.

Table 11.—*German artillery ammunition commonly used in World War II*

Type projectile	Type bursting charge	Weight (whole ammunition)	Fuze	Weapons in which used
		Pounds		
7.5 cm.:				
HE, Type 34	TNT/amatol	12.6	Nose percussion	Geb. G. 36, 1.F.K. 18.
Hollow charge, Type 39	Cyclonite/wax/TNT	9.9	do	Geb. K. 15.
Hollow charge for tank gun	TNT	12.8	do	1.F.K. 18, Geb. G. 36.
Hollow charge for tank gun (Type B).	Cyclonite/wax/TNT	(1)	do	Do.
APC tank gun	TNT and PETN/wax	15.5	Base detonating	1.F.K. 18.
HE, for mountain gun	TNT/aluminum	12.0	Nose percussion; time and percussion.	Geb. K. 15.
Hollow charge for infantry gun	Cyclonite	6.6	Nose percussion	1.I.G. 18.
HE, for infantry gun	Amatol/TNT	13.6	do	Do.
Hollow charge, Type 38	(1)	(1)	do	1.F.K. 18.
APC, tank gun	TNT and PETN/wax	15.4	Base fuze	Do.
Hollow charge for tank gun	(1)	(1)	Nose percussion	1.F.K. 18, Geb. G. 36.
HE, for 75 mm. field gun	TNT	12.75	Point detonating	F.K. 38.
HE, for 75 mm. mountain gun	TNT/aluminum powder	13.25	Time and percussion	Geb. G. 36.
HE	TNT	15	Time and percussion, percussion and delay.	1.F.K. 18.
AP, for tank and field gun	TNT and PETN/wax	15.25	Base fuze	Do.
7.62 cm.:				
HE, Type 39	Amatol	12.64	Nose percussion	F.K. 36 (r).
AP with tungsten carbide core	Tungsten carbide core	9.13	No fuze	Do.
8.8 cm.:				
APC, Type 39	Cyclonite	46.0	Base detonating	Flak 41.
HE, Type L/4.5	Amatol	20.35	Nose percussion or mechanical time.	Flak 18, 36.
AP, for antitank gun	Tubular diglycol	22.8	Base detonating	Flak 36, 41.
AP with tungsten carbide core (Type 40).	Diglycol	16.0	No fuze	Flak 36.
HE, Type L/4.7	Amatol	20.68	Nose percussion or mechanical time.	Flak 41.

APC, for AA gun 18	TNT/wax	20. 75	Base detonating	Flak 18, 36.
HE, for 88 mm. gun	Amatol	20. 5	Time	Flak 41.
HE, L/4.5	do	20. 5	Point detonating	Flak 18, 36.
HE, for AA guns	do	21. 0	Time	Do.
AP	TNT/wax and PETN/wax	21. 0	Base detonating	Do.
AP 39	Cyclonite/wax	22. 0	do	Do.
Incendiary shrapnel for AA gun	TNT or amatol and wax	20. 0	Time	Do.
10.5 cm.:				
HE, Type 19	Amatol	33. 4	Point detonating	s. 10 cm. K. 18 [2].
AP, for howitzer	TNT	30. 9	Base	1.F.H. 18, 1.F.H. 18 (M), 1.F.H. 18/40.
AP	Ethyl/enediamine dinitrate/cyclonite/wax (46/18/36).	34. 5	do	s. 10 cm. K. 18.
HE	(1)	32. 75	Point detonating	1.F.H. 18, 18 (M), 18/40.
HE for light field howitzer	Amatol	33. 5	Point detonating Time and percussion do Point detonating	1.F.H. 18, 18 (M), 18/40.
HE	do	33. 08	Point detonating	1.F.H. 18, 1.F.H. 18 (M), 1.F.H. 18/40.
APC with tracer	TNT	34. 7	Base detonating	s. 10 cm. K. 18.
AP, for light field howitzer	do	34. 62	do	1.F.H. 18, 18 (M).
HE, for field howitzer	TNT or amatol	33. 08	Nose percussion or time and percussion.	Do.
HE, for long distance use in field howitzer.	Amatol	32. 58	do	1.F.H. 18 (M).
Hollow charge	Cyclonite/wax/TNT	25. 56	Nose percussion	1.F.H. 18, 18 (M).
Hollow charge, Type A	do	27. 16	do	Do.
Hollow charge, Type B	do	26. 19	do	Do.
Hollow charge, Type C	do	28. 88	do	Do.
HE, Type 19	TNT	32. 58	Nose percussion or time and percussion.	s. 10 cm. K. 18.
15.0 cm:				
HE, Type 36	(1)	84. 7	do	s.F.H. 18.
Hollow charge, Type 39	Cyclonite/wax	54. 08	Nose percussion	Do.

See footnotes at end of table.

TABLE 11.—*German artillery ammunition commonly used in World War II*—Continued

Type projectile	Type bursting charge	Weight (whole ammunition)	Fuze	Weapons in which used
		Pounds		
15.0 cm—Continued				
HE	Amatol	94. 8	Point detonating	K. 18.
Anticoncrete	TNT	95. 5	Base detonating	K. 18, K. 39.
AP for heavy gun	(1)	99. 25	do	K. 18.
HE, Type 19 with Gaine 36	TNT	95. 7	Nose percussion or time and percussion.	s.F.H. 18.
HE of cast steel	do	105. 4	do	Do.
HE, Type 18	Diglycol	94. 75	do	K. 18, K. 39.
Rodded bomb for heavy infantry gun.	Amatol	105. 0	Nose percussion	s.I.G. 33.
HE, Type 19, for heavy field howitzer.	TNT	95. 7	Nose percussion or time and percussion.	
HE, for gun 16	do	113. 0	do	K. 16.
HE, for heavy infantry gun	do	83. 6	Nose percussion	s.I.G. 33.
HE, Type L/46 with nose fuze	Diglycol	99. 0	Nose percussion or time and percussion.	K. 39.
Semi-AP, for gun 39	(1)	99. 0	Base detonating	Do.
AP, for gun 39	(1)	99. 0	do	Do.
Anticoncrete, Type 19	TNT	95. 7	do	s.F.H. 18.
Rocket-assisted projectile	Diglycol	99. 5	Electric nose percussion, graze operated, instantaneous.	s.F.H. 18.
17.0 cm.:				
HE, Type 38, with ballistic cap	TNT	138. 0	Nose percussion or time and percussion.	K. mit Mörser Lafette.
HE, Type 39	do	150. 0	do	Do.
21.0 cm.:				
Anticoncrete, Type 18	do	268. 0	Base detonating	Mörser 18.

[1] Unidentified.
[2] The Germans refer to calibers approximately; for instance, the 10.5 cm. gun is always known as the "s. 10 cm. K. 18."

FIGURE 26.—Fragments recovered from one of two 50 mm. high explosive shells of a German antitank gun detonated in Zone of Interior.

become real surgical problems when their localization and removal is mandatory, such as in the case of foreign bodies in the eyeball.

Two types of 75 mm. ammunition were tested in August 1943 in the Zone of Interior. One was a standard 75 mm. HE shell, and the other was a 75 mm. HE hollow-charge shell. The fragmentation results are shown in table 12 and figures 27 and 28. It can be seen that the number of fragments per pound for the HE shell was 170, while that for the hollow-charge shell was approximately 185.

TABLE 12.—*Fragmentation characteristics, German 75 mm. HE and hollow-charge artillery shells*

Type of shell	Round	Empty shell weight	Fragments		
			Total	Weight	Recovered
		Pounds	*Number*	*Pounds*	*Percent*
High explosive	1	10. 70	1, 753	10. 35	96. 6
	2	10. 70	1, 634	9. 20	85. 9
High explosive hollow-charge	1	8. 50	1, 374	6. 56	77. 1
	2	8. 51	1, 263	7. 73	90. 8

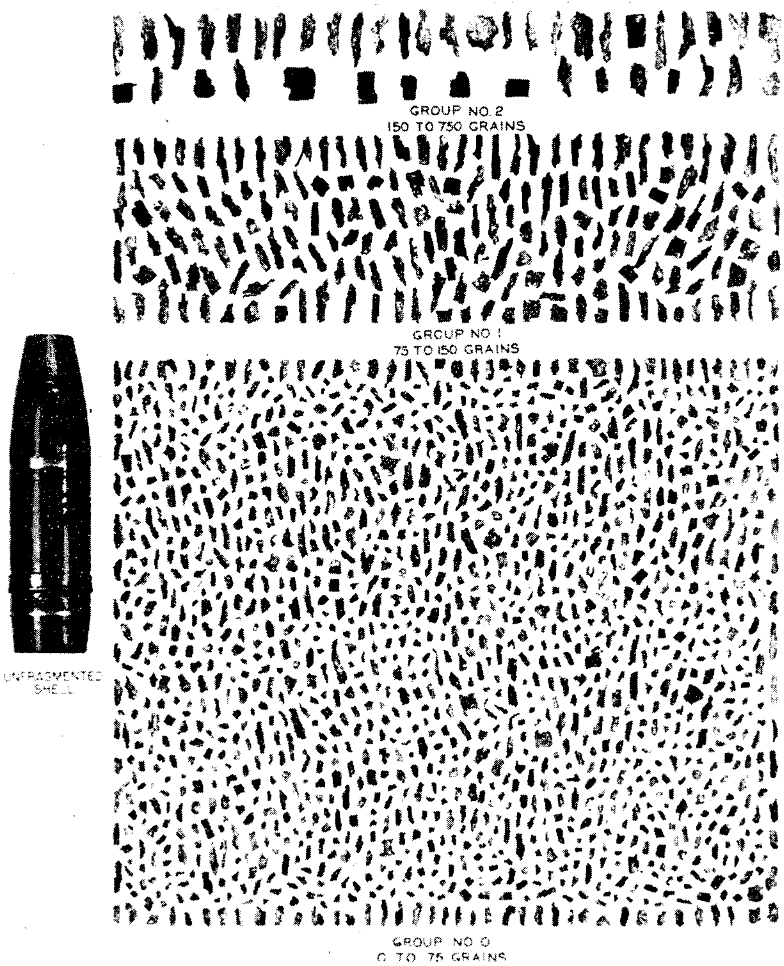

FIGURE 27.—Fragments recovered from a German 75 mm. high explosive shell.

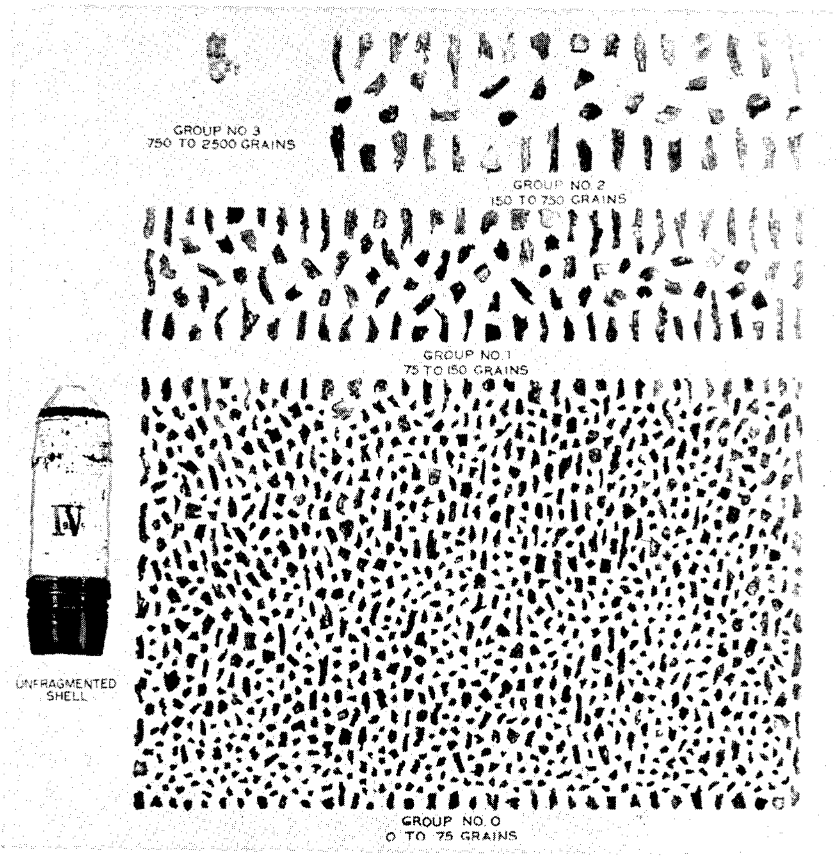

FIGURE 28.—Fragments recovered from a German 75 mm. hollow-charge shell.

In the introduction to this section on German ordnance, it was stated that the German Army made extensive and telling use of AA/AT guns against ground targets as the war went along. Later, it was shown that the original Flak 18 AA gun was so used and eventually modified into the 8.8 cm. Flak 41, which was designed specifically as a multipurpose weapon. Thus, the "88" became a feared weapon, and an AA/AT gun became a casualty-producing weapon of no small consequence.

The HE 88 mm. shells tested were filled with amatol (43/57) and weighed approximately 22½ pounds. The external diameter was 88 mm. (approximately 3½ inches), and the average wall thickness was 0.60 inches. When fired against ground targets, a percussion or time fuze was employed. Two rounds were detonated in January 1943 (fig. 29). The rounds when empty weighed 19.17 and 20.37 pounds. For the first shell, 84.6 percent of fragments—1,488 pieces, 16.2 pounds—were recovered. For the second shell, there was a 78.6 percent recovery consisting of 1,543 fragments weighing 16 pounds. The number of fragments per pound in this experiment was not quite 95, one of

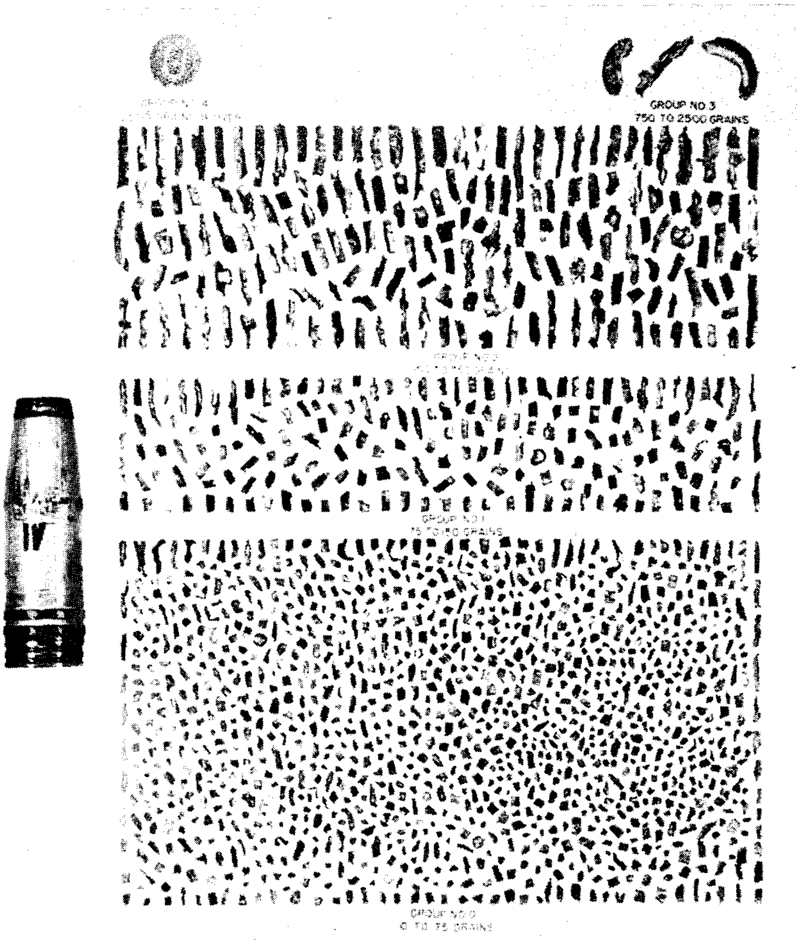

FIGURE 29.—Fragments recovered from a German 88 mm. high explosive shell.

the lowest ratios encountered so far. This finding is actually more apparent than real when one considers the low percent of recovery. The smaller fragments, which are many, were probably not recovered.

Other static detonation tests of the 88 mm. HE shell were conducted. The basic data included fragmentation results and the mean, minimum, and maximum velocities of fragments over the first 10 feet. From this basic data, the data shown in figure 30 were derived. The method of derivation was basically the same as that explained in the preceding section on mortar ammunition (p. 53).

Fragmentation tests conducted in January 1942 on two rounds of German 105 mm. howitzer ammunition (fig. 31) showed the following characteristics: The rounds when empty weighed 28.55 pounds. For both shells, 91 percent of the fragments were recovered. For the first shell, there were 2,540 pieces,

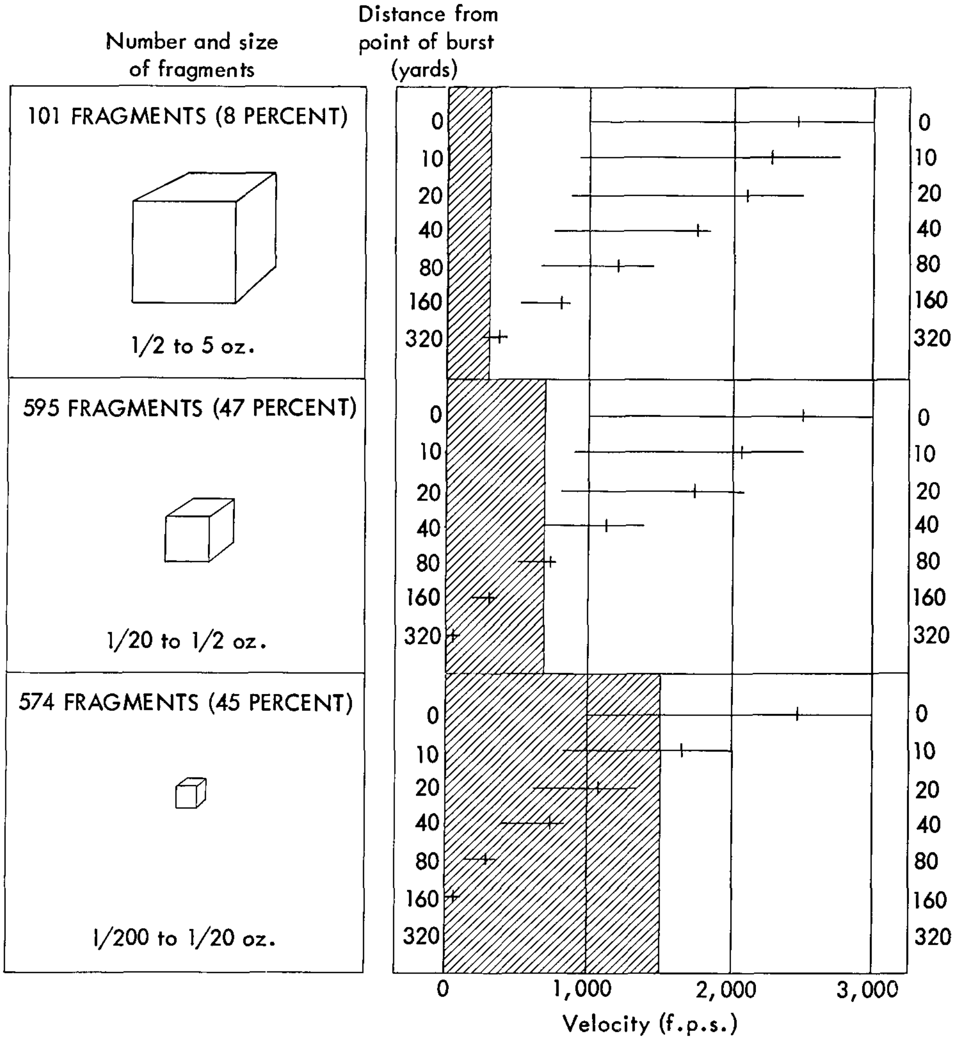

FIGURE 30.—Fragmentation characteristics, German 88 mm. high explosive artillery shell. The horizontal lines for velocity give expected ranges of velocities, and the vertical intersecting lines give the most probable velocities. The shaded portions show velocities below the incapacitation criterion.

weighing 25.98 pounds; for the second, 2,063 pieces, weighing 26.03 pounds. In this case, the number of fragments per pound was considerably below 100, but it is obvious that the fragments are larger in size when their numbers are less per pound. This may be due to the fact that the shell wall is thicker. While the number of fragments is less, their size and the amount of bursting charge will make a larger percent capable of inflicting casualties. The reader

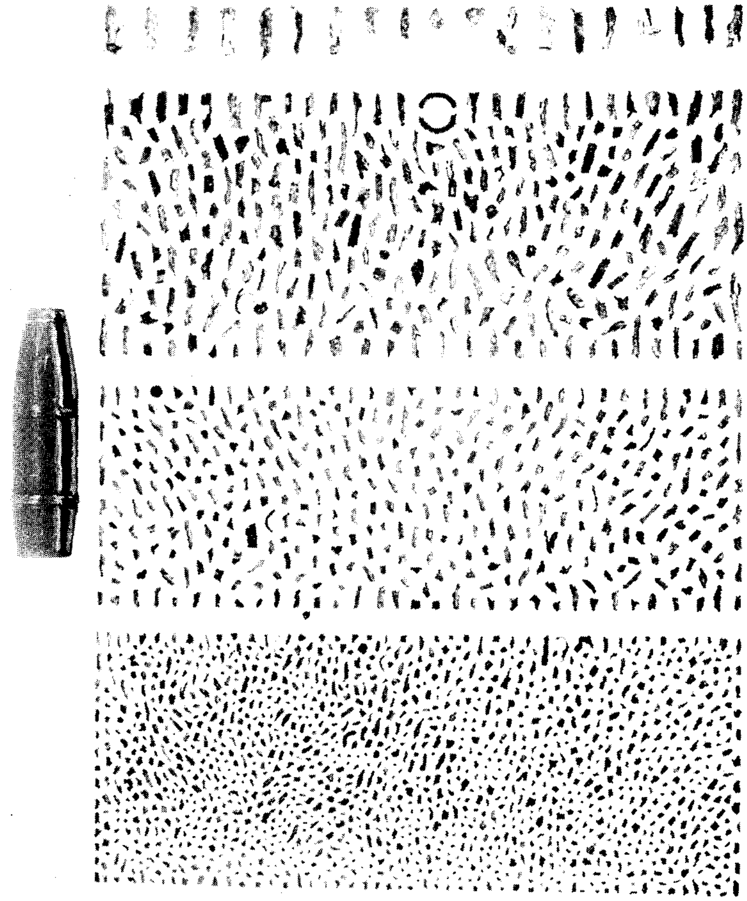

FIGURE 31.—Fragments recovered from two rounds of German 105 mm. howitzer ammunition.

should note that, while stressing the number of fragments in these reviews of detonation tests, there was usually no information available on any criterion of wounding, particularly in relation to the effective radius of burst. The latter should be considered in relation to absolute number of fragments.

Other Missile-Producing Agents

The German ground forces employed a wide variety of hand, rifle, and signal pistol grenades for both antipersonnel and AT purposes. The standard HE hand grenade was a stick hand grenade (Stielhandgranate 24) which consisted of a hollow wood handle and a thin sheet metal head containing the explosive filler. The grenade would detonate from 4 to 5 seconds after a pull

on the porcelain ball located at the base of the wood handle. This grenade had a total length of 14 inches and weighed 1 pound 5 ounces. Stielhandgranate 43 was a modified version of the foregoing grenade with a detachable solid wood handle. The grenade could be thrown with or without the wood handle. A smooth or serrated fragmentation sleeve could be clipped around the head of the grenade to increase its antipersonnel effect.

In addition to the standard stick-type grenade, two other offensive-type hand grenades had a similar design. A wood improvised grenade (Behelfshandgranate-Holz) consisted of a hollow cylindrical wood head screwed on a hollow wood handle. The head contained a 50-gram bursting charge. The other offensive-type grenade was a concrete improvised hand grenade (Behelfshandgranate-Beton). This was very similar to the wood grenade except that the head was made of concrete and contained a full 100-gram bursting charge. Both grenades were designed to produce blast effects rather than primary fragmentation and were used by troops advancing in the open.

Of the standard German hand grenades, Stielhandgranate 24 and the egg-type grenade (Eierhandgranate 39) were the most commonly used forms. This latter grenade consisted of a thin sheet metal egg-shaped case filled with a 4-ounce bursting charge and had a friction pull ignitor with a 4- to 5-second delay. The grenade had a total length of 3 inches, was 2 inches in maximum diameter, and weighed 12 ounces.

Another offensive type was a disk grenade which had no outer casing but consisted of a disk cut from a precast or pressed pellet of explosives. The disk was prepared from the explosive RDX/wax and measured 3⅝ inches in diameter and 17/32 inch in thickness. A standard pull ignitor and detonator assembly with a 6-second delay was inserted into the disk.

During the latter stages of World War II, the Germans issued a unique hollow-charge AT hand grenade (Panzerwurfmine 1 (L)) which was designed to be hand thrown at tanks from a distance of 20 to 30 yards. The grenade body consisted of a metal core containing the explosive filler and concave metal retaining plates at the forward end. A hollow-charge sticky hand grenade was also recovered which consisted of a tapered steel body with a flat sticky pad at the nose.

Several HE rifle grenades were used by the Germans and, since these were primarily antipersonnel weapons, they were capable of producing missile casualties. The Gewehr Sprenggranate antipersonnel rifle or hand grenade could be fired from a standard cup-type rifle discharger or thrown as a hand grenade. It consisted of a tubular steel body containing a penthrite wax explosive filler, a direct-action nose fuze, and a base assembly incorporating a flash pellet, delay train, and self-destroying system. When the grenade was launched from the rifle, it was initiated normally by the PD fuze, but if this failed the flash pellet in the base would ignite a friction composition which in turn would ignite a 4½-second delay pellet initiating the detonation of the main bursting charge. The latter method of detonation was, of course,

designed primarily to function when the grenade was used as a hand grenade. Various modifications of this grenade were issued and these included models in which the pull ignitor for hand throwing was omitted, the self-destroying assembly was lacking, or an "all-ways" point fuze was embodied which would initiate the charge no matter which way the grenade would strike. The standard model had a maximum range of 265 yards as a rifle grenade. A later model (Gewehr Sprenggranate mit Gesteigerter Reichweite) of the HE hand or rifle grenade was fired by a new propelling charge and had a maximum range of only 71 yards. In addition, the self-destroying device was eliminated. In both cases, the propelling charge was a standard 7.92 mm. blank cartridge with a wood bullet crimped at the neck and sealed with wax.

Antitank grenades, although intended for use against armor, would frequently inflict secondary-missile casualties. The standard AT rifle grenade (Gewehr Panzergranate 30) consisted of a seamless steel tubular forward section containing a ballistic cap, hollow-charge cone, and TNT bursting charge and a rear portion made up of light aluminum alloy containing a fuze and exploder system. The large AT rifle grenade (Gross Gewehr Panzergranate 40) was a slight modification of the Gewehr Panzergranate 30 to accommodate a greater bursting charge. Two additional hollow-charge rifle grenades were also issued, and they were similar in design but varied in that one (S.S. Gewehr Panzergranate 46) had a maximum diameter of 46 mm. and the other (S.S. Gewehr Panzergranate 61) had a maximum diameter of 61 mm.

An HE hollow-charge grenade (Gewehr Granatpatrone 30) consisted of a streamlined bell-shaped body with a slightly convex aluminum closing disk, an aluminum hollow-charge liner cast with an RDX/wax filler, and a graze fuze screwed into a projection at the base of the body. The grenade exploded when it hit an object or merely grazed a target.

A number of antipersonnel and chemical grenades could be fired from the 27 mm. signal and grenade pistol. The standard German signal pistol (Leuchtpistole) was a smoothbore weapon and fired a variety of 40 different signal cartridges and two kinds of HE pistol grenades. One of the latter, Wurfgranatpatrone 326, consisted of a small HE projectile fitted to a signal cartridge case. The second type, Wurfkörper 361, consisted of a standard egg-type grenade attached to a projectile stem which fitted into a loose smoothbore barrel liner.

The Kampfpistole was a later modification of the Leuchtpistole with the addition of a small sight and rifling of the bore. With these alterations, a nose-fuzed HE grenade could be fired in addition to the standard signal cartridges. In the latest development of the signal pistol, the original model was fitted with a loose steel rifled liner, a combination front and rear sight, and a folding stock. By means of these alterations, the pistol could fire a new-type hollow-charge grenade at close quarters against tanks.

Other Fragment-Producing Agents, Landmines

German landmines had undergone a rather extensive developmental program and a wide variety of models were encountered in the field. The Tellermines (T. Mi. 29, 35, 42, and 43) were metal AT mines of a flat circular, design which varied in size, shape, area of pressure plate, and in type and amount of the bursting charge. The Sprengriegel 43 was a rectangular, encased charge of TNT which could be fired electrically but required a pressure of approximately 440 pounds for activating the ignitors. A wood box mine (Holzmine 42) was also issued for use as an AT device or as a boobytrap. The body consisted of a wood box of three-quarters of an inch lumber which was divided into four compartments by removable partitions. Two explosive charges of 50/50 amatol were placed in the two side compartments; the central compartment contained the primer charges and the end compartment, the operating mechanism. A completely nonmetallic AT mine was the Topfmine which had a hard pulplike outer casing and a glassed ignitor.

One of the most commonly encountered antipersonnel mines was the "Potmine" (Behelfs-Schützenmine S.150) (fig. 32). The pressed steel body

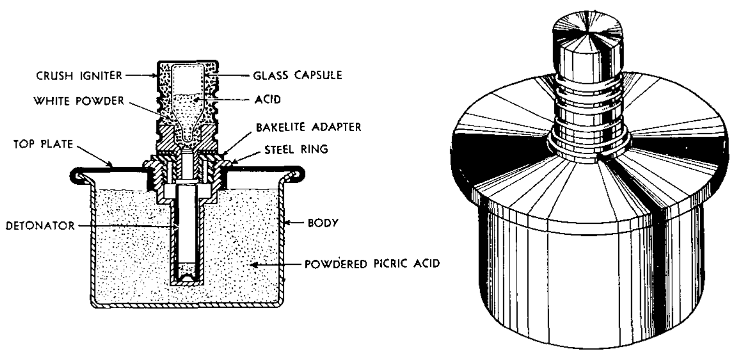

FIGURE 32.—Antipersonnel mine, Behelfs-Schützenmine S.150.

was 2½ inches in diameter and 2 inches high. When filled with a 5¼-ounce explosive charge of powdered picric acid, the total weight of the mine was 12½ ounces. A moderate pressure on the top of the ignitor would crush the metal drum, break a glass ampule filled with acid, and thereby permit a chemical interaction between the acid and a white powder flash composition. The resulting flash set off the detonator which ignited the main bursting charge.

During the course of World War II, the Germans utilized a number of mines which depended upon shrapnel for their antipersonnel effect. One of these, the S. Mine 35 (fig. 33) was 5 inches high, 4 inches in diameter, and weighed 9½ pounds. There was an outer steel casing within which was fitted an inner steel cylinder. The latter contained an ignitor, a central delay tube,

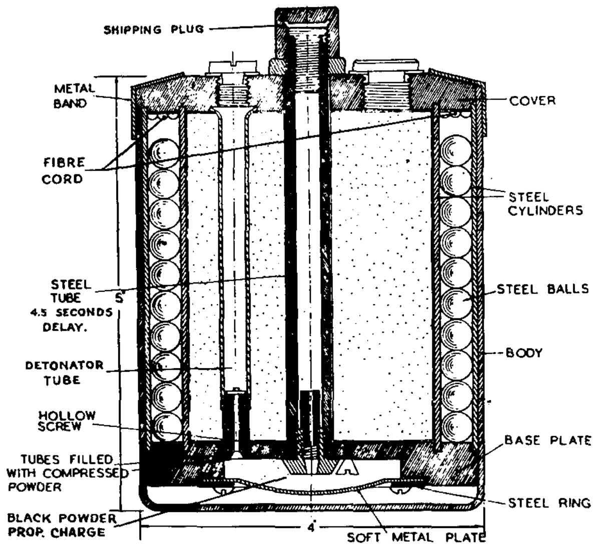

FIGURE 33.—Antipersonnel shrapnel mine (S. Mine 35).

a black powder propelling charge, a main explosive charge, and approximately 350 steel balls, rods, or scraps of metal alined along the cylinder wall. A direct pressure of approximately 15 pounds activated a push-type ignitor. A pull-type ignitor could be connected to trip wires, while an electric squib-type ignitor could be fired by electrical means. In any case, when the ignitor fired, flashes of flame descended the central steel tube and set off the black powder propelling charge which threw the inner cylinder into the air. Concurrent with this, the detonator was ignited which, in turn, set off the main charge. The delay in the detonation of the main charge permitted the inner cylinder to rise from 6 to 7 feet above the ground before its casing would be fragmented to release the steel shrapnel balls. The latter would be effective up to a radius of 150 to 200 yards.

The S. Mine 44 was of the same basic design as the S. Mine 35 but varied in the method of igniting the main charge and in the use of many layers of small steel shot. An inner cylinder contained a detonator, a pull ignitor, and a percussion ignitor. The latter was actuated by a direct pressure of 21 pounds or by a tension of 14 pounds applied through lateral trip wires. The pull ignitor was located in the base of the cylinder immediately below the detonator. It was attached to the base of the outer casing by a 3-foot length of coiled wire. Operation of the percussion ignitor fired a fast-burning gunpowder propellant which caused the inner cylinder to be thrown upward. When the coiled wire was fully extended at about 1½ feet above ground level, the pull ignitor activated the detonator which, in turn, set off the main explosive charge. Accordingly, the small steel shrapnel balls were released at a lower level than in the S. Mine 35 and the effective radius was less—110 yards with a 22-yard lethal radius.

In an attempt to reduce the metallic content of the antipersonnel mine and increase the difficulty in its detection, a glass mine (Glasmine 43 (f)) was developed. This consisted of an outer glass casing 4.2 inches in height, from 4½ to 6 inches in diameter, and from 0.25 to 0.40 inch in thickness. Approximately 40 pounds of direct pressure was required to break the glass shear plate and activate either a chemical or a mechanized ignitor. Several models of wood antipersonnel mines were also manufactured and employed against infantry, cavalry, and light vehicles. The Schü-Mine 42 consisted of a casing of impregnated plywood or hardened compressed fibrous cardboard filled with a 100-gram explosive charge. Two other wood mines—Models 42(N) and 43(N)—were also encountered which consisted of an impregnated wood body with a cast TNT filler. The 42(N) mine functioned when a pressure was applied to an ignitor located in the top of the body, and the 43(N) was detonated when pressure on the lid sheared two wood dowels on the front of the body and released the safety pin. The functioning load of the ignitors used in both of these mines was approximately 75 pounds. Mines similar to the Schü-Mine were to become favorite defensive weapons of the Communist forces in North Korea.

Distribution of Weapons

As in the case of Japanese ordnance, the reader would be left unaware of the relative amount of use made of the weapons described unless he had some idea of how they were distributed. The division organization in the German Army (table 13) was the basic unit of combined arms. From the outbreak of the war until the late summer of 1943, comparatively minor changes occurred in the tables of organization of most types of German divisions. The average strength for that period was from 15,000 to 17,000 and, with normally attached troops, usually reached some 20,000 men. From the summer of 1943 on, however, several series of new tables of organization and equipment were issued. In all the reorganizations, the trend was clearly toward economizing manpower and simultaneously increasing firepower by a careful distribution of large numbers of automatic small arms, by lowering the number of mortars, AT guns, and tanks, and, at the same time, by increasing potentially their calibers and weights. These changes resulted in lowering the table of organization strength of a division to approximately 11,000 to 13,000 in January 1945. By that time, however, many divisions were actually of only about regimental strength in able bodies.

The infantry division, old type, was the basic German division from the fall of Poland until summer, 1943. Like the American triangular division, it consisted of three regiments, each with three battalions. The 1944-type division was the midpoint in a reorganization from the old type to a drastically reduced division in 1945. The fundamental revision was the reduction of battalions from three to two per regiment, platoons from four to three in the rifle companies, and accompanying reductions throughout the division. The *Volks Grenadier division*, three regiments of two battalions each, was one of

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TABLE 13.—*Weapons and equipment of main types of German divisions*

Weapon and equipment	Type of divisions								
	Infantry, old type	Infantry, 1944 type	Infantry, two regiment type	*Volks Grenadier*	Army Mountain	Army Motorized	Army Armored	*SS* Armored	Air Force Parachute
Rifles or carbines	15, 500	9, 069		6, 054		9, 455	9, 186	11, 513	9, 689
Pistols	1, 100	1, 981		1, 536		3, 222	3, 317	4, 064	3, 810
Submachineguns	700	1, 503		2, 064		1, 441	1, 543	2, 050	3, 026
Light machineguns	527	566	497	369	485	1, 019	1, 157	1, 465	930
Heavy machineguns	116	90	52	54	84	82	64	100	80
Mortars:									
81 mm	58	48	42	42	48	52	46	58	125
120 mm		28	24	24	24	24	16	24	63
Bazookas or AT rifles	90	108		216	72				250
Flamethrowers	20	20	16	12	20	26	68	74	20
Rocket projectors, 150 or 210 mm								18	
Guns:									
AA, 20 mm		12	12		12	75	74	114	39
AT, 20 mm., or tank	11					38	38	38	
AT, 28/20 mm							3	3	
AA/AT, 37 mm				9	3		8	8	
AT, 75 mm. (Mtr-Dr)	75	21	20	9	24	30	12	12	21
AT, 75 mm. (Sp)		14		14		44	47		14
Tank, 75 mm. (long)						48	52	64	
Tank, 75 mm. (superlong)							51	62	
AA/AT, 88 mm			12			8	8	12	12
75 mm				18	24				
Infantry howitzers:									
75 mm	20	18	12	38	14				20
75 mm. (Sp)							12	24	
150 mm	6	6	4		4				
150 mm. (Sp)						12	12	12	

Gun/howitzers:									
105 mm	36	36	24	24	12	12	12	12	24
105 mm. (Sp)						12	12	12	
Howitzers:									
150 mm	12	12	12	12	12	12	12	[1] 12	12
150 mm. (Sp)						6	6	6	12
Pz. Kpfw:									
IV						48	52	64	
V								51	62

[1] Also furnished were 12 heavy guns.

the latest organizations and reflected in name and weapons the emergency which had approached the fatherland. There is a further decrease in personnel, an increase in the proportion of small automatic weapons per man, and the substitution of medium artillery with larger numbers of light artillery. The other types of divisions are shown for comparative purposes and to round out the picture.

CAUSATIVE AGENTS OF BATTLE CASUALTIES IN WORLD WAR II

In order to determine which type of enemy weapon was most effective against U.S. troops in World War II, it would be necessary to know the causative agent for each wound inflicted. Not only was such information impossible to get for all areas for the entire war period but what was available was often inaccurate. Casualties who survived were frequently not able to determine the weapons that had wounded them. For those killed outright or who died of wounds, no opinion was available if there had been no witnesses. Prompt interment of bodies seldom left time for recovery of the missile that killed. Casualty surveys which supplied this type of information were made only in certain areas at specified times. However, these studies used different methods of reporting, and the lack of a uniform system made assessment and comparison of reports difficult.

Nevertheless, many interesting facts can be brought out from the material available. A report on the causative agents of battle casualties in World War II showed the comparative incidence of casualties from different types of weapons for several theaters. Compilers of the report believed that, while the more detailed subdivisions within their three major classes were open to question, their findings on the percent of total casualties due to small arms, artillery and mortars, and "miscellaneous" were reasonably accurate. From these they drew the following conclusions:

1. Small arms fire accounted for between 14 and 31 percent of the total casualties, depending upon the theater of action: The Mediterranean theater, 14.0 percent; the European theater, 23.4 percent; and the Pacific theaters, 30.7 percent.

2. Artillery and mortar fire together accounted for 65 percent of the total casualties in the European and Mediterranean theaters, 64.0 and 69.1, respectively. In the Pacific, they accounted for 47.0 percent.

The report showed the relative effectiveness of causative agents which inflicted casualties on 217,070 living wounded of the First and Third U.S. Armies, European Theater of Operations, 1944–45 (table 14).

It is also interesting to note from two tables taken from studies conducted on Bougainville and in Italy that more casualties in the South Pacific were caused by rifle or machinegun fire than in the North African theater:

South Pacific

Agent		*Percent*
Shell fragments		50
Bullets:		
Rifle	25	
Machinegun	8	
		33
Grenade		12
Mines		2
Other		3
Total		100

North Africa

Agent	*Percent*
Shell fragments	75
Bullets	20
Mines	2
Bombs	1
Other	2
Total	100

TABLE 14.—*Frequency distribution of casualty-producing agents in 217,070 living wounded, First and Third U.S. Armies, 1944–45*

Causative agent	Wounded	
	Number	Percent
Small arms	53, 334	24. 6
Artillery and mortar:		
Shell fragments	130, 718	60. 2
Blast	6, 880	3. 2
Bombs	10, 559	4. 9
Burns	2, 498	1. 2
Other	13, 081	5. 9
Total	217, 070	100. 0

NORTH KOREAN FORCES ORDNANCE MATERIEL

The weapons used by the CCF (Chinese Communist Forces) in the Korean War were of diverse origins and types. The relatively limited munitions production in China before 1950 had forced the CCF to rely heavily upon weapons captured from the Japanese, the Chinese Nationalists, and the U.S. forces. With the signing of the Chinese Communist-Soviet 30-year mutual assistance pact in February 1950, Soviet weapons became available in increasing numbers, but, initially, the CCF entered Korea without Soviet weapons. Later, these Soviet weapons were supplemented by Chinese copies of foreign designs and by limited quantities of weapons from almost every other arms-manufacturing country including Great Britain and France.

The NKA (North Korean Army) was from the outset equipped with Soviet weapons of World War II vintage. Throughout the period of the Korean War, Soviet weapons captured in Korea continued to be those manufactured in or earlier than 1950.

Pistols and revolvers.—Pistols and revolvers among the Communist forces in North Korea had little combat significance because of the much more effective use by half-trained troops of the machine pistol or the submachinegun. They were, however, still issued to officers, service troops, combat and transportation vehicle crews, and flying personnel as weapons of personal defense. Over a dozen types were available in calibers from 6.35 mm. to 11.4 mm. The most common pieces used were the Japanese 8 mm. pistols, 7.63 mm. Mauser pistols of both German and Chinese manufacture, and Soviet 7.62 mm. pistols and revolvers.

Submachineguns.—The submachinegun was one of the principal weapons of the Communist troops in Korea. Various models of the U.S. Thompson submachinegun and the caliber .45 M3, including copies made in Chinese arsenals, were widely distributed to CCF troops.

Before 1950, the U.S.S.R. began supplying the North Koreans with Soviet 7.62 mm. PPSh1941 and PPS1943 submachineguns. These were also issued to the CCF following their disastrous spring offensive of 1951. The PPSh1941, the more prevalent, was a blowback operated, semiautomatic or full-automatic weapon with a 71-round drum or 35-round box magazine. The improved all-metal version of 1943, the PPS43, was also blowback operated but fired full automatic only. Both weapons used the standard 7.62 mm. Soviet auto-pistol cartridge. Effective ranges in the earlier model were approximately 330 yards semiautomatic, 220 yards in short bursts, and 110 yards in long bursts. The practical rate of fire varied between 40 and 150 rounds per minute depending on whether it was firing semiautomatic, in short bursts, or in long bursts. The PPS1943 had a practical rate of fire of 100 rounds per minute and an effective range of approximately 220 yards for short bursts and 110 yards for long bursts. As the war progressed, the Chinese Communists began to produce copies of these models in substantial numbers.

Rifles and carbines.—The enemy in North Korea used rifles obtained mainly from four sources: Those captured from U.S. forces or from forces armed by the United States, those captured from the Japanese, those supplied by the Soviet Union, and those manufactured for or by China during or after the days of the Republic.

The most important of the U.S. weapons used were the .30-caliber M1 rifles and carbines. It was reported that whole units of the CCF were armed with the M1 carbine. The 1903 Springfield was also used extensively.

Japanese 6.5 and 7.7 mm. rifles and carbines were very popular during the first years of the Korean War. These were gradually replaced by the Soviet bolt-action rifles and carbines chambered for the powerful 7.62 mm. Soviet service cartridge. The 7.62 mm. M1944 carbine, formerly the standard shoulder arm of the Soviet infantry, was also frequently employed by the Communist forces. This was a shorter version of the earlier Russian standard infantry rifle, the M1891/30, also commonly used by the North Koreans. The M1944 weighed 8.6 pounds with sling and had a practical rate of fire of approximately 10 rounds per minute and an effective range of 440 yards.

Those arms manufactured earlier for, or by, Nationalist China were all chambered for the 7.92 mm. service cartridge. Among these were different models of the conventional bolt-action Mauser rifles, the ZH 29 Czech autoloading rifle, and some 1888 German rifles.

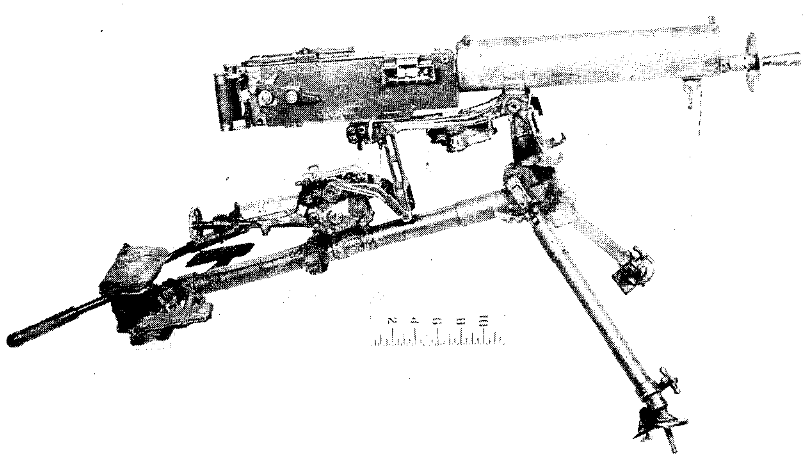
Machineguns.—The CCF in North Korea acquired their machineguns in much the same way as they did their rifles and carbines. In the light machinegun class, they had captured a limited supply of Browning Automatic rifles and 1919A4 light machineguns from U.S. forces and from forces of other countries armed with weapons made by the United States. Some caliber .50 Browning heavy machineguns of U.S. manufacture were also used. From the Japanese, they had taken substantial quantities of 6.5 and 7.7 mm. light and heavy machineguns, including the 6.5 mm. Model 11 (1922), the 6.5 mm. Model 96 (1936), and the 7.7 mm. Model 99 (1939) light machineguns and the Types 92 and 01, 7.7 mm. heavy machineguns. These types were discussed in the section on Japanese ordnance materiel.

Of Soviet origin were the various Degtyarev machine rifles and light machineguns represented by the DP, the DPM, and the DTM. All three types were gas operated and air cooled, and all used the standard 7.62 mm. series of cartridges. The feeding device of the DP and the DPM was a 47-round drum magazine, and each model weighed about 26 pounds with loaded drum. The practical rate of fire was 80 rounds per minute with an effective range up to 880 yards against group targets. The DTM had a 60-round drum magazine and was used both as a tank and as a ground gun.

Two other Soviet weapons used were the 7.62 mm. Maxim M1910 heavy machinegun (with an effective range of 1,100 yards and a rate of fire of 250–300 rounds per minute) and the 7.62 mm. Goryunov M1943 heavy machinegun which was a modification of the Maxim with similar performance but much lighter. There was also a 12.7 mm. (caliber .50) DShK M1938 AA machinegun. The DShK M1938 had a practical rate of fire of 300–350 rounds per minute and an effective range of approximately 3,000 feet when used against aircraft and approximately 3,300 yards when used as a ground gun.

The Chinese themselves manufactured copies of two excellent weapons—the ZB 26 light machinegun and the Maxim heavy machinegun (fig. 34), both of which fired 7.92 mm. ammunition. The ZB 26 was gas operated and either semiautomatic or full automatic. It weighed close to 20 pounds and had a 20-round box magazine. Effective range was 875 yards with a rate of fire of 150–200 rounds per minute. The Chinese Maxim was practically identical to the 1908 Maxim but with considerable changes in the mount.

Mortars.—Mortars manufactured in Chinese Communist factories and those captured from the Japanese, the Chinese Nationalists, and the United Nations Forces in Korea were used extensively by Communist forces in North Korea, often as a substitute for artillery. Those produced in Chinese Communist arsenals were the 60 mm. Model 31 (copy of the U.S. M2), the 82 mm. Model 20, and the 120 mm. Model 44. Captured U.S. materiel included the 60 mm., the 81 mm., and the 4.2-inch mortars. Japanese models used were all



OCO, D/A A67073

FIGURE 34.—CCF Maxim heavy machinegun, 7.92 mm., Model 24.

81 mm. weapons. Three models of the Soviet 82 mm. battalion mortars, the M1937, M1941, and M1943, were widely used. These Soviet weapons weighed about 12.7 pounds each and fired HE shells up to 3,326 yards. The Soviet 120 mm. mortar (figs. 35 and 36) remained as effective in Korea as it was during World War II when used by both the Red Army and the Germans.

Artillery.—Until the close of World War II, when they acquired quantities of Japanese-made artillery, the CCF lacked both artillery materiel and experience in its use. Their supply of artillery was increased between 1946 and 1949 with the capture of considerable amounts from the Chinese Nationalists, including modern U.S. made field artillery. With Soviet aid in the Korean War, the CCF received quantities of Soviet artillery, as the North Koreans had before them.

Captured Japanese infantry guns and mountain artillery which the CCF used were the Type 92 (1932) 70 mm. battalion howitzer and the 75 mm. Type 41 (1908) infantry and Type 94 (1934) mountain guns. Limited quantities of the U.S. 75 mm. pack howitzer M1A1 and Soviet 76 mm. regimental and mountain guns and 76 mm. howitzers were also used in addition to various other 75 mm. pieces of French, German, Japanese, and Swedish origin.

Field artillery employed by enemy troops consisted primarily of weapons made in Japan, the United States, and the Soviet Union. Light artillery used was made up largely of several types of Japanese 75 mm. guns and 105 mm. howitzers and field guns, Soviet 76 mm. divisional guns, and the U.S. 105 mm. howitzer M2A1. Ballistic characteristics for the Japanese models have been given previously. The Soviet 76 mm. (M1942) divisional gun, weighing 2,460 pounds, was capable of firing a 13.7-pound HE projectile a maximum distance of 14,550 yards. The Soviet 57 mm. AT Gun (M1943) was also extensively used.

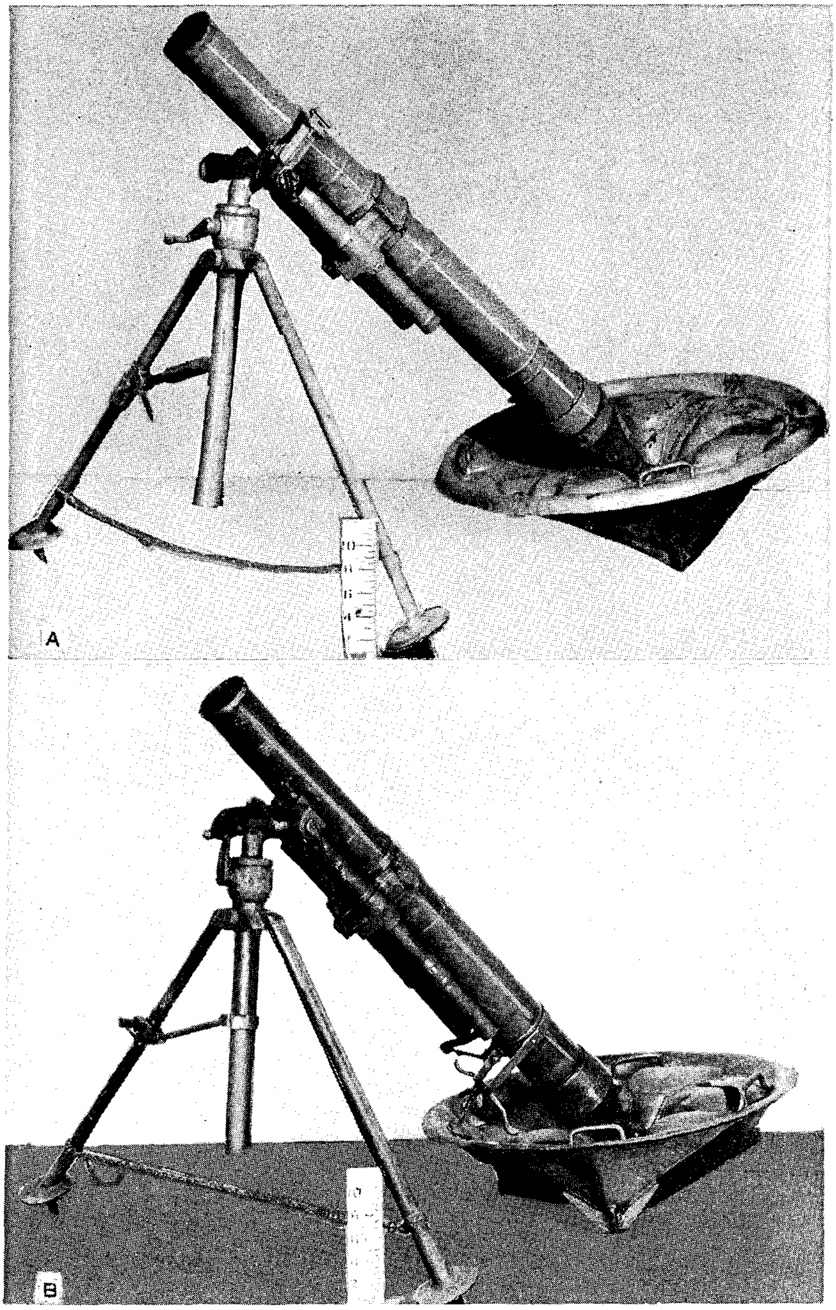


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FIGURE 35.—Two versions of the Soviet 120 mm. mortar. A. Model 38 from the European Theater of Operations, World War II. B. Weapon captured in Korea.

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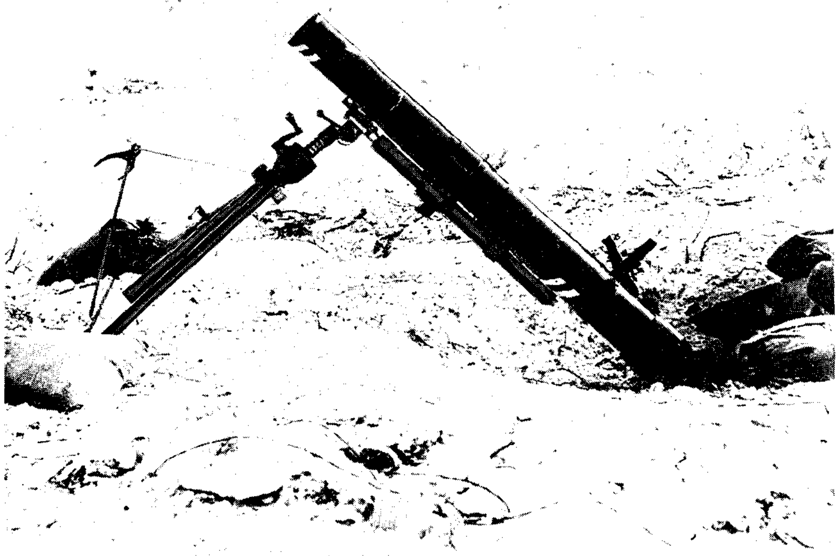
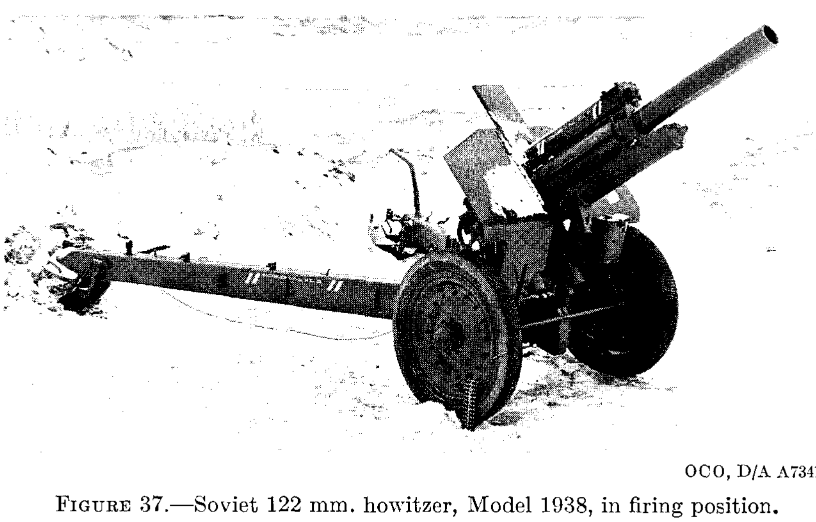


OCO, D/A A75101

FIGURE 36.—Soviet 120 mm. mortar, Model 1943. Weapon in firing position after firing two seating rounds. Elevation 45°.

Most important of the Soviet medium field artillery pieces used included the 122 mm. howitzer M1938 (fig. 37), the 122 mm. corps gun M1931/37, and the 152 mm. gun howitzer M1938. The M1938 howitzer weighed 4,960 pounds, had a maximum range of 12,900 yards, and fired an HE projectile weighing 48 pounds. The 122 mm. M1931/37 corps gun weighed over three times as much as the M1938 howitzer and was capable of firing a 55-pound projectile 22,750



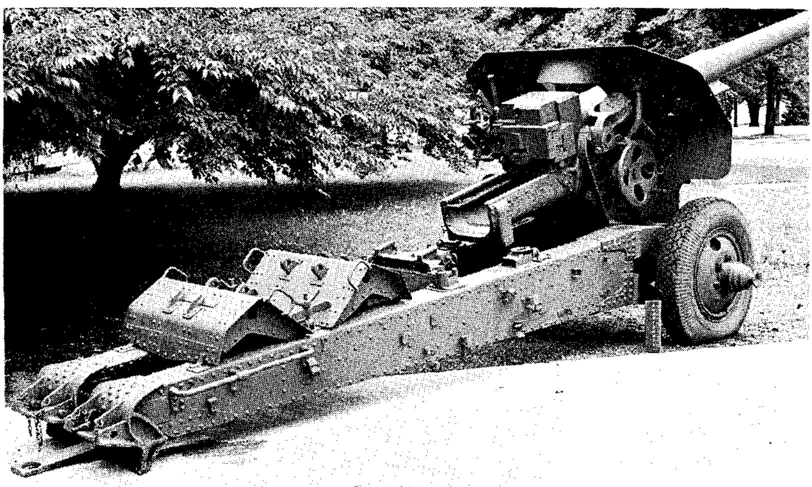
OCO, D/A A73412

FIGURE 37.—Soviet 122 mm. howitzer, Model 1938, in firing position.

yards. The 152 mm. (M1938) gun howitzer (fig. 38), heaviest of the three, fired a 96-pound shell approximately 18,880 yards.

Japanese 150 mm. howitzers and guns and a small number of U.S. 155 mm. howitzers M1917A1 were employed along with a variety of British, French, and German weapons ranging in caliber from 75 mm. to 150 mm.

The Chinese Communists manufactured fairly exact copies of the smaller Japanese artillery pieces but did not attempt to duplicate the larger ones. Among the principal models copied were the 75 mm. Type 41 (1908) infantry gun, the 75 mm. Type 94 (1934) mountain gun, and the 70 mm. Type 92 (1932) infantry howitzer.



OCO, D/A B18645

FIGURE 38.—Soviet 152 mm. gun howitzer, Model 1938 (M10), with carriage.

Rocket launchers.—The Communists in North Korea were again supplied by the Soviet Union in the matter of rocket launchers. The model issued was the 8-railed 132 mm. M13 which fired 16 fin-stabilized HE rockets. Maximum range of the 94-pound rockets was approximately 9,500 yards. This weapon, normally mounted on a 6 x 6 truck, possessed relatively good mobility and heavy-fire effect but lacked the range and accuracy of conventional artillery. For this reason, it was used primarily to cover area targets since fire against point targets was not practical.

The Chinese Communists designed and manufactured a six-round rocket launcher, 102 mm. A3, from which they fired a Chinese copy of the U.S. 4.5-inch rocket. This launcher was mounted on a two-wheeled carriage and was light enough to be transported by truck.

Ammunition.—North Korea was almost completely dependent upon the Soviet Union for the ammunition it used during the Korean War. Some Japanese and captured U.S. ammunition was also used.

The Chinese Communists depended largely on ammunition derived from different foreign nations, but they also manufactured some modified or exact copies of products of several other nations. At the close of World War II, they acquired quantities of Japanese ammunition. When they gained control of the Chinese mainland in 1949, large Chinese Nationalist stocks were captured, and Nationalist arsenals were seized. These arsenals, many originally inherited from the Japanese by the Nationalists at the close of World War II, continued to produce Japanese-type ammunition for the Communists. Varying amounts of British, Swedish, French, Italian, and German types were

TABLE 15.—*Communist China and U.S.S.R. small arms ammunition used by NKA and CCF* [1]

Nomenclature	Type of construction	Projectile		Weapons in which used
		Length	Weight	
7. 62 mm:		*Inches*	*Grains*	
Type 50	Ball	0. 55	87	Type 50 submachinegun, Type 51 automatic pistol.
Type R	Unidentified	. 65	108	Nagant revolver M1895.
Type P	do	. 55	87	TT Pistol M1933; all Soviet submachineguns.
Model 1908, Type L	Ball	1. 12	150	All Soviet 7.62 mm. rifles, carbines, and machineguns.
Model 1930, Type D	do	1. 30	185	Do.
Model 1930, Type B-30.	AP	1. 30	184	All Soviet 7.62 mm. ground machineguns, rifles, and carbines.
Type unidentified	AP, tracer	1. 58	157	Soviet 7.62 ground machineguns and rifles.
Model 1940, Type BS-40.	AP, incendiary	1. 20	187	In shoulder weapons only.
Model 1932, Type B-32.	do	1. 44	155	All Soviet 7.62 mm. machineguns and rifles.
Type BZT	AP, incendiary, tracer.	1. 58	142	Do.
12.7 mm:				
Type unidentified	HE, incendiary	2. 48	660	DShK M1938 AA machinegun.
Model 1930, Type B-30.	AP	2. 45	788	Do.
Type BS-41	AP, incendiary	(2)	(2)	Do.
Type unidentified	do	2. 50	725	Do.
Model 1932, Type B-32.	do	2. 46	745	Do.
Type BZT	AP, incendiary, tracer.	2. 49	681	Do.

[1] Communist China was the country of origin for the Type 50 small arms ammunition; the U.S.S.R. was the country of origin for all the other ammunition.
[2] Unconfirmed.

also collected. Soviet ammunition was received in large amounts following CCF entry into the Korean War and was used along with the U.S. ammunition which the enemy captured. The Chinese Communists manufactured .45 caliber small arms ammunition which literally defied differentiation from U.S. .45 caliber ammunition when discovered in casualties. Initially, CCF use of this ammunition caused considerable consternation since no foreign nation had ever manufactured and used .45 ammunition against American soldiers.

Ammunition manufactured by the Chinese Communists was erratic in quality—sometimes good and sometimes poor. Reasons for this were loose manufacturing standards, lack of adequate forces of skilled workers, unsatisfactory machinery, and shortages of raw materials. Often, small arms cartridges were picked up after firing with cracked necks. Deficient packaging of the ammunition frequently resulted in serious deterioration of originally undefective contents.

General characteristics of ammunition commonly used by the enemy in Korea and not previously described are presented in tables 15, 16, and 17.

TABLE 16.—*Communist China and U.S.S.R. mortar ammunition used by the NKA and CCF* [1]

Projectile	Explosive charge	Fuze	Weight (Complete round) [2]	Weapons in which used
			Pounds	
60 mm:				
HE mortar shell	TNT	Point detonating	3.25	Type 31 mortar.
HE mortar shell (long). [3]	RDX	do	8.0	Do.
82 mm:				
HE mortar (6 fins) [4]	Cast TNT	Instantaneous	8.59	Type 20 (1931) mortar.
HE mortar (8 fins)	do	Point detonating	8.29	Do.
0.832 mortar shell, fragmentation.	Schneiderite/TNT.	do	6.95	Various 82 mm. mortars.
0.832 D	Amatol 90/10	do	6.95	Do.
120 mm:				
HE mortar (short) [5]	Potassium nitrate/TNT 50/50.	do	28.75	Type 33 (1944) mortar.
HE mortar (long) [6]	Cast TNT	do	27.88	Do.
HE mortar (extra long).	TNT	Point detonating impact.	46	Do.

[1] The U.S.S.R. was the country of origin for the 0.832 and 0.832 D mortar ammunition; Communist China was the country of origin for the other mortar ammunition.

[2] Without increments.

[3] This shell has supplementary 120 mm. warheads filled with TNT.

[4] This shell has 6 fins for stabilization.

[5] This shell has 8 fins.

[6] This shell has 12 fins.

TABLE 17.—*U.S.S.R. artillery ammunition probably used by NKA and CCF*

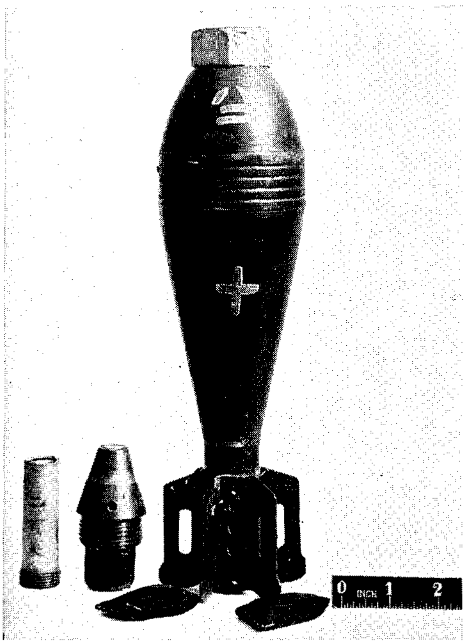
Caliber	Weight (complete round)	Type of projectile filler	Fuze [1]	Weapons in which used	Type of burst [2]
Mm.	*Pounds*				
37	3.23	TNT	MG–8	Model 1939 AA Gun	Fragmentation.
All 76	12–25	TNT, amatol, schneiderite, TNT cyclonite, cyclonite aluminum, or ball shrapnel and black powder.	High velocity AP have no fuze or use a KTM–1, KTM–3, KT–1, KT–3, T–5, T–11, MD–5, MD–7, D, BM, 3GT, 22-second, or 22 PG.	Divisional guns, tank guns, self-propelled guns, AA guns, mountain guns, 76 mm. regimental guns.	Fragmentation, high explosive, and combined fragmentation-high explosive.
All 122	56–89	TNT, amatol, RDX and aluminum, RDX/TNT, shrapnel and black powder.	High velocity AP have no fuze or use an RG–6, RGM, RGM–2, RGM–3, D–1, MD–8, V–229, 45-second, or T–6.	122 mm. howitzers, corps guns, tank guns, self-propelled guns.	Combined fragmentation-high explosive and high explosive.
All 152	99–131	TNT, ball shrapnel	RGM, RGM–2, RGM–6, RG–6, D–1, KTMF, KTD, 45-second, or T–6.	152 mm. howitzers, self-propelled guns.	Do.

[1] Soviet artillery fuzes, in general, are of orthodox design. They are classified by location on the projectile, in two main categories: (1) Point detonating and (2) base detonating. They are also classified by their type of action as impact, combination time and impact, or time fuzes.

[2] Soviet artillery uses three kinds of HE projectiles: (1) *Fragmentation*, designed to destroy personnel, equipment, and aerial targets by means of fragments; (2) *high-explosive*, intended primarily to destroy temporary field fortifications, such as trenches and earth and timber emplacements, as well as to destroy personnel and equipment, by means of blast effect; and (3) *fragmentation-high explosive*, a combination of the other two types. It gives less fragmentation and greater blast effect than the fragmentation projectile but greater fragmentation and less blast effect than the HE projectile. The fragmentation effect predominates over the blast effect in fragmentation high explosive projectiles of calibers up to 122 mm. and the blast effect predominates in calibers of 122 mm. and larger. The fragmentation-high explosive projectile is used against the same targets as the fragmentation and the high-explosive; the setting of the fuze determines whether its principal effect will be fragmentation or blast.

Again in Korea, the mortar was used extensively. It was the ideal weapon for the relatively close-in fighting in rugged mountainous terrain which characterized much of the operations in Korea. Whether it was inadvertent or intentional is debatable, but, in Korea, the Communist use of cruder cast metals in mortar shells seemed greatly to increase the number of fragments per shell and the effectiveness of their antipersonnel mortar fire when compared to conventional steel-walled shells. Often, the number of fragments per shell was many times that described previously for Japanese and German rounds. The apparent crudeness of the CCF mortar shells can be seen in figures 39, 40, 41, and 42, showing various 82 mm. and 120 mm. shells.

Figure 43 shows the CCF copy of the American M48, 75 mm. artillery round.



OCO, D/A A93396

FIGURE 39.—CCF 82 mm. mortar shell, model unidentified.

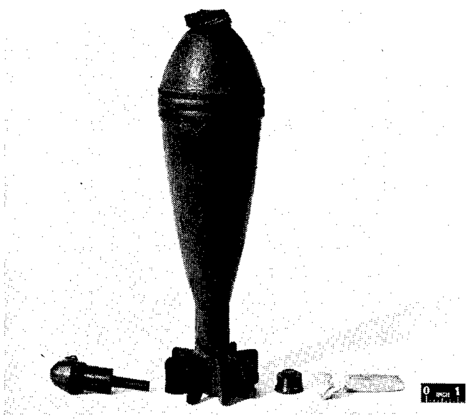


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FIGURE 40.—CCF 82 mm. mortar shell, model unidentified, with eight fins and point-detonating fuze.

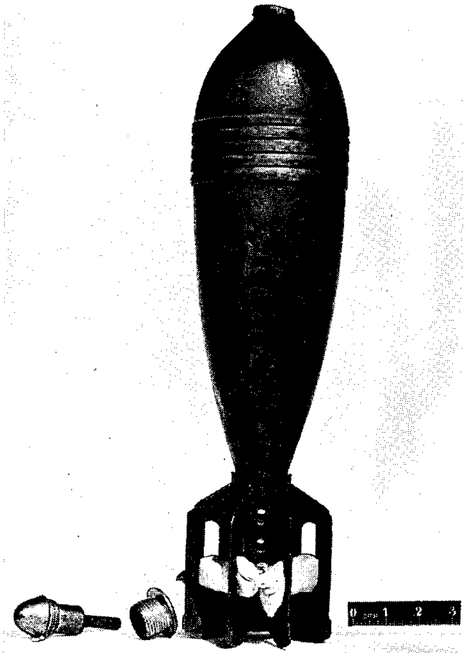

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FIGURE 41.—CCF short 120 mm. mortar shell, high explosive.

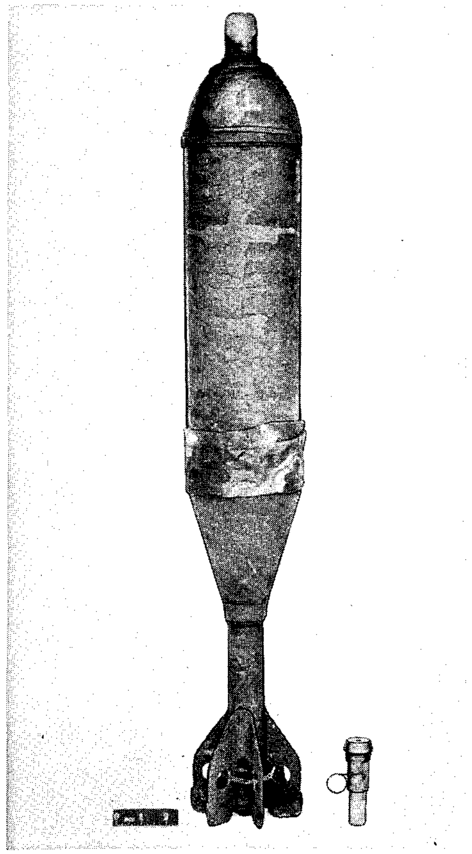

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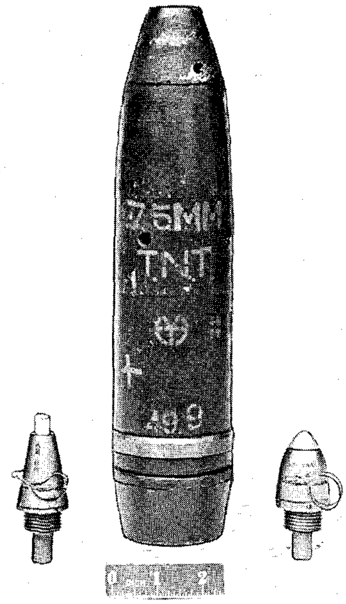
FIGURE 42.—CCF extra long 120 mm. mortar shell, high explosive model unidentified, with long fin shaft and six fins.

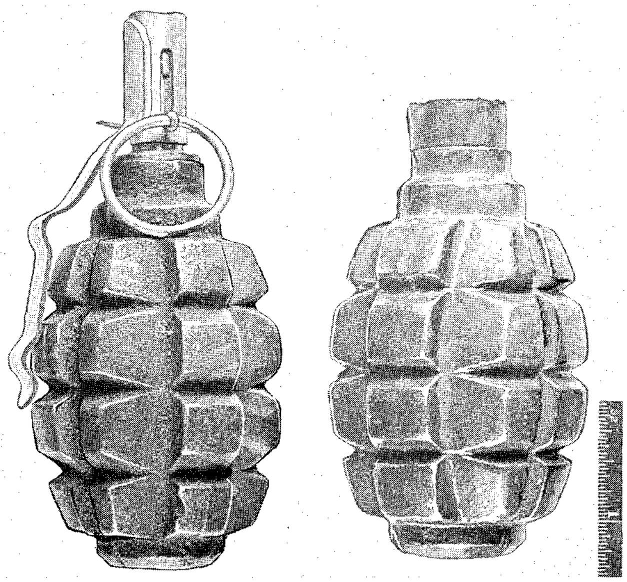
Grenades.—Grenades of wide variety were used liberally by the Communist forces in Korea because of the relative ease and cheapness of their manufacture and because of the general shortage of heavy weapons and artillery among the troops. The most common, as well as the most effective types, were stick hand grenades, fragmentation hand and rifle grenades, and HEAT hand grenades, all of Chinese manufacture. Effective also were Soviet RPG–43 and RPG–6 HEAT hand grenades and the Soviet F–1 fragmentation grenade (fig. 44).

The Chinese-made stick hand grenades were similar to the German "potato-masher" type in design. They were liable to be filled with anything, but picric acid was common. Even dynamite-filled grenades were found! Most of the grenades had a friction pull-type ignitor. The fuze was instantaneous to 6-second delay. The HEAT grenades depended upon a fiber or



OCO, D/A B1953

FIGURE 43.—CCF copy of U.S. M48, 75 mm. high explosive shell, with adapter and point-detonating fuze, Model 88 (instantaneous or delay).



OCO, D/A 50530

FIGURE 44.—Soviet fragmentation hand grenade, F–1, with fuze.

cloth tail for stabilization. One of this type, the Type 3 HEAT hand grenade had an overall length of 7 inches and an instantaneous impact type of fuze.

The Soviet RPG–43 HEAT hand grenade was filled with 1.35 pounds of cyclotol and had an instantaneous impact fuze. Average range was 17–22 yards with an effective radius of fragmentation of 22 yards. The Soviet RPG–6 had about the same average range as the RPG–43 but was filled with TNT and had an effective radius of fragmentation of 25 yards.

Landmines.—Landmines were used extensively by the enemy because their use afforded them a chance to improvise and allowed them to utilize fairly effective "homemade" weapons. Their standard antipersonnel models were designated Landmine No. 8 and Armor-Piercing No. 4. Two Soviet models commonly employed were the PMD–6 and PMD–7 which closely resembled the German Schü-Mine. Weighing under a pound each, these wood box-shaped mines had a cylindrical charge of TNT and an MUV pull fuze. Because of the lack of metal parts in their construction, they were hard to detect with mine detectors.

Improvised models were in many different forms such as bangalore torpedoes, artillery and mortar shells, aerial bombs, and hand grenades. They also were in explosive-filled containers such as tin cans, wood boxes, fuel drums, barrels, glass bottles, clay pots, or other types of containers. Detonation could be accomplished either by trip wire, pressure, or automatic firing circuit.

Because of fluctuations in battle—up and down the length of Korea—a large number of mine casualties were caused by mines planted by friendly personnel in the defense and during retrograde movements.

CHAPTER II

Ballistic Characteristics of Wounding Agents

Maj. Ralph W. French, MAC, USA (Ret.), and Brig. Gen. George R. Callender, USA (Ret.)

PHYSICAL ASPECTS OF THE MISSILE CASUALTY

Warfare between individuals or nations to be carried to a successful conclusion requires rendering the enemy noncombatant through injury, or death, and concomitant loss of his ability to function within his assigned duties. In modern warfare, antipersonnel weapons have been developed which are capable of injuring the enemy at a considerable distance from the origin of attack, and means, such as the atomic bomb, have been devised for the wholesale destruction of enemy personnel and materiel. While destruction of materiel plays a role in modern warfare, inflicting injury to cause incapacitation of personnel still remains the most important consideration.

To develop perspective for fair appreciation of modern warfare and its weapons, it is necessary to go back to prehistoric time. It is logical to presume that the earliest warfare was hand-to-hand combat. This was probably quickly augmented by sticks, clubs, or other similar and readily available aids. Following this, prehistoric man no doubt commenced to hurl stones or other missiles easily grasped and thrown. From this stage, it was not too great a step to increasing missile velocity through the aid of the sling, throwing stick, or other means to add to the missile velocity and consequent effectiveness. In brief, man took advantage of the physical law of kinetic energy which remains as the fundamental law in the study of missiles and the formation of wounds.

Considering early history as recorded in the Bible, it is noted that David, in his encounter with the giant, Goliath, was conversant with the advantage to be gained through augmenting his personal strength with small, smooth stones which could be hurled effectively with the sling. This offset the inherent advantage of the giant's strength. It resulted in a missile casualty.

As we come down through recorded military history, we see man aiding his military effectiveness in rendering the enemy hors de combat with the hand-hurled spear or javelin followed by the arrow propelled by the bow or crossbow. In this stage, we see man also adding to his ability by using the horse as a means for increased velocity and force in propelling the spear. However, the arrow was often capable of inflecting injury at greater ranges than possible for hand-to-hand encounter and had excellent ballistic qualities. In this period, there

also was the use of various antimateriel weapons, such as the catapult for throwing stones. Ever since this era, there has been a decrease in the size of the missile and an increase in velocity and consequent range of effectiveness.

With the advent of gunpowder at the battle of Crécy in the 14th century, the potential for greatly increased missile velocities with ability to produce injuries at greater ranges became apparent. However, development was relatively slow, as gunpowder in its earliest applications was often more dangerous to friend than to foe. Metallurgy, chemistry, physics, and the manufacture of weapons had yet to be developed to permit the commonplace applications of modern warfare.

The gunpowder available for many years was dangerous as its rate of transformation into gas could not be accurately controlled and as it also deteriorated on slight provocation. This resulted in many serious disasters through weapon failure. Only with the advent of the so-called smokeless powders could rate of burning be controlled and pressures be held within safe limits.

From the 14th to the 19th centuries was seen the development of small arms through the blunderbuss, musket, and rifle and the development of artillery from the crude wooden cannon to the metal smoothbore and the rifled artillery piece. Smokeless powder with its controllable rate of burning was a 19th century invention. In this period also was seen the use of explosive charges in grenades and landmines, as well as the development of explosive missiles for artillery use.

In the 20th century came the airplane with its potentialities of transporting bombs many miles from the point of origin to inflict injury on enemy personnel and to destroy materiel. There also was marked improvement in powders and other explosive agents.

Analytical retrospection of the entire development of warfare from prehistoric time reveals man's continual struggle to augment his human capability to inflict injury through the utilization of the law of kinetic energy as applied to the moving object. There is a continual trend down through the centuries toward the infliction of injury at even greater distances through increase in missile velocity. In this respect, the airplane is only an agent to carry the missile of destruction to yet greater distances from the point of origin. It results in greatly increased effective battle ranges.

Along with this general trend, it also is noted that an increasingly greater number of people are involved in major military operations with ever-increasing effort toward the development of more and more firepower.

Missile effectiveness has been observed to be a function of velocity, and, in keeping with this, it was but natural that through the ages there has been a continual increase in missile speeds. Before the advent of gunpowder, missile velocities at best could not exceed several hundred feet per second. From the 14th to the beginning of the 20th century, missile velocities were increased to approximately 2,000 f.p.s. (feet per second). In the period 1900–1918, velocities were again increased up to approximately 4,000 f.p.s. From that

date to 1953, and taking the atomic bomb into consideration, missile velocities have been increased to approximately 20,000 miles a second. No doubt some of the radiation components of the atomic bomb have greater velocities than this. However, gunpowder and its related agents were responsible only for a velocity increase to something more than 7,000 f.p.s., the greater increase being due solely to the nature of atomic fission and its reactions.

Progressively, the outstanding steps in this analysis of missile warfare and its development down through time follow: Clubs, stones, sling, bow to propel an arrow, gunpowder, rifle, smokeless powder, TNT and related propellants, airplane, rockets and rocket-propelled bombs, and the atomic bomb.

From this brief résumé of the progressive development of the missile as an antipersonnel agent, it is natural to inquire just how that missile produces a casualty. While medical men have served with the armies for many years, it was only recently that studies to determine the mechanics of wound production have been instituted. There has been some observation and many reports but little organized research, mainly because available instrumentation was inadequate for a serious, comprehensive study.

Better appreciation of the detailed mechanics of wound production has a dual purpose. First, a more complete knowledge of the wound and its extent permits better definitive treatment by the military surgeon; second, this knowledge permits the design of ordnance materiel for antipersonnel purposes on scientific grounds. It also lessens the need for costly rule-of-thumb or "cut and try" methods by either the military surgeon or the ordnance engineer.

It is the purpose of this chapter to bring together the salient principles regarding the missile casualty as a physical entity, a cause and effect phenomenon. These principles explain many apparent anomalies as seen by the surgeon unacquainted with the detailed mechanics of wound formation and may aid the ordnance engineer in his design problems.

Frequently, the military surgeon has seen small entrance and exit holes in the skin of a gunshot casualty and taken it for granted that the internal damage was correspondingly small. Had he known more of the modern high-velocity rifle bullet and what is known as yaw, the trivial external wounds would not have misled him in his initial treatment of the wound. Also, had he been appreciative of the true magnitude of the forces involved, his mental picture of the wound would have been far more accurate.

For many years, the ordnance designer gaged the effectiveness of missiles by their ability to penetrate pine boards or similar materials. However, when an accidental discharge of a shrapnel round raised a serious doubt as to the real value of shrapnel as an antipersonnel agent, this rule-of-thumb gage was found to be valueless as a criterion. The ordnance designer wanted some "real" information from the medical man of what was necessary to produce a casualty.

For the sake of a comparable yardstick in evaluation of ordnance materiel, a missile with 58 ft.-lb. (foot pounds) of kinetic energy was considered to be capable of producing a casualty. While this has not been fully substantiated

as a fair criterion, it is well supported [1] and is definitely superior to pine boards. No doubt, under optimal conditions, a missile with considerably less energy than 58 ft.-lb. can produce a serious wound, but on the average it is probable that this amount of energy will insure a casualty.

Though much has been accomplished in a comparatively short time in explaining many of the factors entering into the physical formation of the wound, much remains to be learned. There is the question of how the yawing rifle bullet produces such damaging injuries. There also is the question of nerve injuries—their cause, extent, and repair. Again, just how much debridement is necessary to insure repair? These are but a few of the physical, physiological, and pathological problems yet to be answered.

The Missile Source [2]

Small arms.—In considering the missile casualty, small arms naturally fall into several classifications based on the character of wound. For the purpose of this discussion, small arms will be considered as those weapons so classified by the Office of the Chief of Ordnance, U.S. Army, with a caliber of approximately 0.60 inch or less.

Sidearms.—These are small weapons designed primarily for personal defense. In World War II, some automatic weapons in this category also were designed for effective offensive employment at near ranges. Muzzle velocities ranged from a little more than 800 f.p.s. for the U.S. sidearms up to nearly 1,200 f.p.s. for those used by the Germans. The comparatively low velocities produced minimal wounds.

Carbine.—In the U.S. Army, the .45 caliber pistol was often replaced by a .30 caliber carbine firing a 110-grain bullet with a muzzle velocity of 1,975 feet per second. This was a semiautomatic weapon useful for offensive as well as defensive action. It also was used by paratroopers and others requiring a small, effective weapon. While essentially a shoulder weapon, the ballistic characteristics placed it more in the category of a super sidearm, and missile casualties from this weapon were more of the sidearm type.

Shoulder weapons.—The basic offensive weapon of the foot soldier is the shoulder weapon. From the lessons learned in World War I, the trend in military weapons has been toward the development of semiautomatic arms to relieve the soldier of the interruption due to loading the weapon. Consequently, there has been an increase in the rate of aimed fire and firepower. However, many repeating rifles of the older magazine type were used in World War II. From the missile-casualty standpoint, the most important consider-

[1] The 58 ft.-lb. rule was never completely acceptable to all the workers in the field, and a major effort has been initiated to supplant this rule with more definitive medical criteria. The 58 ft.-lb. of kinetic energy was based upon an early German principle and probably was meant to be applicable only to lead spheres weighing half an ounce and measuring half an inch in diameter.—J. C. B.

[2] (1) Catalogue of Standard Items. 2d ed. Office of the Chief of Ordnance, Washington, D.C., 1944, vols. I, II, and III. (2) Catalogue of Enemy Ordnance Materiel, Office of the Chief of Ordnance, Washington, D.C., 1945, vol. I (German); vol. II (Japanese).

ation is the muzzle velocity of the shoulder weapon projectile, as this largely determines the effective range and the type of wound. In World War II, the muzzle velocities of the Japanese rifles ranged from 2,200 to 2,400 f.p.s.; of the German rifles, from 2,500 to 2,700 f.p.s.; and the muzzle velocities of some of the U.S. shoulder rifles were slightly more than 2,800 f.p.s. In general, at combat ranges, comparatively severe wounds are to be expected from any of these weapons, much more so than the wound produced with the usual sidearms missile and velocity.

Machineguns.—In the machinegun category are the antipersonnel full automatic weapons using essentially the same ammunition as the shoulder weapons of corresponding caliber. Weapons of this type in the larger calibers are primarily antimateriel agents and will be considered later in their secondary antipersonnel aspect. As a missile-casualty agent, machineguns are essentially the same as shoulder weapons except for one important factor. Full automatic weapons fire at a high cyclic rate, 400–800 rounds a minute. This commonly results in multiple wounds, all of a severity to be expected with the shoulder weapon missile. This also accounts for the fact that the machinegun missiles proportionately produce a greater number of fatal casualties.

Automatic weapons larger than 8 mm. (0.315 in.).—While classed as small arms, weapons in this category (most of them 0.50 inch in caliber) are designed primarily for aircraft, AA (antiaircraft), and antimateriel purposes. The larger size of projectile permits the practical use of an HE (high explosive) bullet as well as other types of missiles designed for specific purposes. While some wounds are certain to be caused by these missiles, the casualty is usually incidental to the use of the weapon for other missions.

Antitank small arms.—The Germans had three types of 7.92 mm. (0.312 in.) nonautomatic AT (antitank) guns of interest. One, an ex-Polish model, had a muzzle velocity of 4,100 f.p.s., while the other two had muzzle velocities of 3,540 f.p.s. Early in World War II, these weapons were quite effective and were capable of penetrating more than an inch of armor at a range of 100 yards. However, with the increase of tank armor protection, they lost their value and became effective only against light-armored vehicles. The high-muzzle velocities are of interest, though it is unlikely that many missile casualties can be ascribed to these weapons.

Ammunition.—For sidearms and shoulder weapons, ball-type ammunition is generally employed. This usually consists of a lead core protected with a jacket of gilding metal or similar material. Most bullets in military use are sharp pointed, having the so-called spitzer nose. Some have a flat base while others are boattailed. Some medium-velocity ball ammunition is used with the carbines or other special defensive weapons.

Small arms ammunition commonly used with machineguns and aircraft and AA weapons in the small arms category includes:

1. Ball ammunition.
2. Incendiary ammunition.
3. Incendiary with tracer ammunition.

4. Tracer ammunition.
5. Armor-piercing ammunition.
6. Ball with tracer ammunition.
7. High explosive ammunition.

While casualties may occur with any or all of these various types of bullets, other than ball, the primary use of these bullets is for other purposes. Most of the varied types of ammunition find their greatest use in aircraft and AA work. However, under certain ground conditions, tracer, incendiary, and AP (armor-piercing) types are of value in machinegun missions.

Wounds resulting from tracer, incendiary, or HE bullets are complicated by various effects peculiar to the particular missile. Tracer and incendiary bullets not only introduce the factors peculiar to their chemical characteristics but usually produce severe wounds because of their comparative lack of stability, their low cohesiveness, and their poor ballistic characteristics resulting from loss of mass. They often yaw badly and break up on impact. Wounds often suggest the use of explosive bullets. While international agreement had prescribed the HE missile for small arms use, the Japanese had such bullets for their 7.7 and 12.7 mm. weapons, presumably for use in aircraft and AA weapons. However, in view of the fact that aircraft often strafed personnel, the complaint regarding wounds from HE bullets was logical.

Japanese 6.5 mm. bullet with enlarged core in the base.—In correspondence,[3] it was suggested that this bullet was probably launched at velocities higher than those usually credited to the Japanese 6.5 mm. ammunition. This was believed erroneous because of the weight of the bullet. The 6.5 mm. rifle was a comparatively old gun, and no doubt materials inferior to those available in modern weapons had been used in its construction. It also was not designed for chamber pressures common in more modern weapons. The bullet weighed 138 grains (figs. 45 and 46) and was homologous with a 161-grain .30 caliber bullet. A bullet homologous with the 150-grain .30 caliber bullet would weigh 129 grains.

Knowing the chamber pressures necessary to launch a 161-grain bullet in the .30 caliber rifle with a velocity comparable to the 150-grain bullet, it was logical to presume that the Japanese fired this bullet at a muzzle velocity of 2,300–2,400 f.p.s., usually credited to their standard 137.3-grain bullet.

However, the spin imparted to the bullet by the rifling would have a negligible effect in effecting stabilization in denser mediums, such as tissues. In fact, the increased mass in the tail of the bullet would undoubtedly operate to increase greatly the degree of yaw on entering a dense medium. This bullet would probably have slightly less stability in air than one of a more conventional design, so that the degree of yaw on impact would normally be somewhat larger also.

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[3] Memorandum, Deputy Chief, Small Arms Development Branch, Technical Division, Office of Chief of Ordnance, 19 Feb. 1943, for Col. George R. Callender, MC, Army Medical Center, Washington, D.C., subject: Japanese Caliber .256 Bullets, with enclosures thereto.

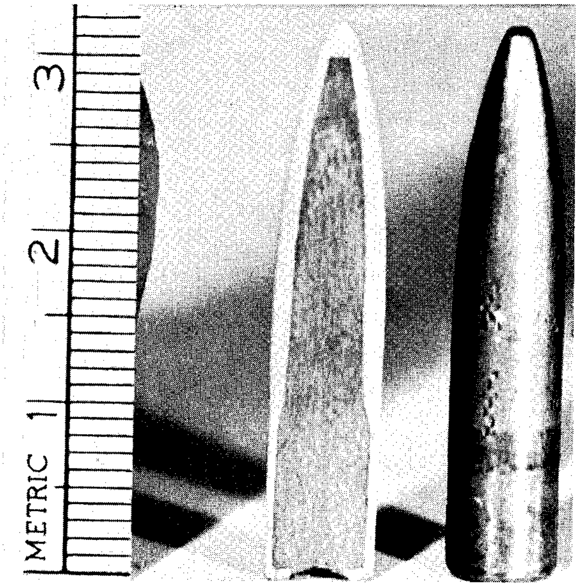

FIGURE 45.—Japanese 6.5 mm. (0.256 in.) bullet with odd-shaped core of antimony lead mixture. Shape of core changed dynamic characteristics of the bullet so that it was apt to cause severe wounds at near range because of excessive yaw. Weight of the bullet was 138 grains. (Magnification three times actual size.)

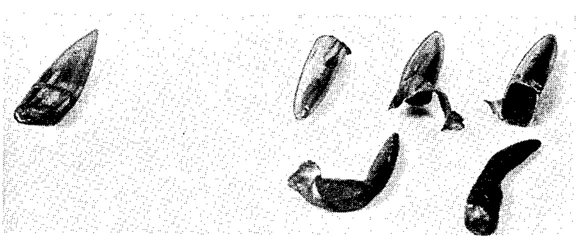

FIGURE 46.—Japanese bullets with peculiar core recovered after being fired into water. To the left is a U.S. M1 bullet fired and recovered in the same manner for comparison. The Japanese bullets deformed at the base as is commonly noted with military full metal patch bullets with the spitzer nose on impact at velocities in excess of 2,000 f.p.s. It was also noted that the core separated from the jacket in two cases. This last was also noted in wounds produced by this Japanese bullet in jungle fighting at near ranges.

In general, it has been observed that with sufficient velocity all cored metal-jacketed bullets will break up or deform on impact. The most resistant to disintegration is the sharp-pointed spitzer bullet. However, at close ranges and impact velocities in excess of 2,400 f.p.s., this bullet often shows deformation, with breakup appearing first in the base of the bullet. On the other hand, the round-nosed bullets break up at velocities from 1 to 2 thousand feet less, but their first deformation occurs at the nose. Bullet breakup or deformation of the full metal patch missile is most apt to occur on impact with hard bone.

Soft-nose hunting-type bullets break up at lower velocities and often commence to disintegrate in the skin immediately after impact. Fragments of jacket and lead core are found in quite superficial tissues when impact velocities are excessively high—2,200 f.p.s. or more.

Projectile, artillery.—Although in all wars before World War II various antipersonnel loads such as canister, grapeshot, chain shot, and shrapnel were used, experience had conclusively demonstrated the comparative ineffectiveness of these agents for antipersonnel purposes. The HE projectile, however, had proved to be not only more effective in producing casualties but had also proved capable at the same time of inflicting materiel damage which is often of greater importance in carrying out the artillery mission.

The HE projectile is capable not only of penetrating an earthwork but, after the penetration, of detonating and producing casualties in the personnel, supposedly protected by the earthwork, by the many high-velocity fragments resulting from the detonation. Various types of contact, delayed action, and time fuzes permit almost uncanny timing of projectile detonation.

Ineffectiveness of the special antipersonnel cannon loads has been due in the past to the comparatively low projectile velocities at battle ranges. Though this was not so apparent at the battle ranges common to warfare before the 20th century, it became a certainty with the experiences of World War I. The advent of smokeless powder, better types of steel, and manufacturing improvements made practicable increased artillery muzzle velocities, but these factors did not materially increase the effective remaining projectile velocities. The battle ranges increased commensurately with the increase in muzzle velocities so that remaining velocities remained essentially constant.

On the other hand, fragments resulting from the detonation of HE projectiles have increased materially in effectiveness as antipersonnel agents. Control of burst has been much improved through more accurate fuzing. Initial fragment velocities have been more than doubled (from less than 3,000 to more than 6,000 f.p.s.) by the utilization of new explosives. Fragmentation has been controlled also through improved projectile design and through the selection of better fragmenting materials in construction.

High-explosive detonation charges have resulted in a much greater number of effective fragments than was possible with the other types of antipersonnel projectiles. For instance, the total number of balls in a 3-inch shrapnel load was less than 300 compared to the thousand-odd effective fragments from a 75 mm. HE shell at 20 feet from the point of burst. The 81 mm. HE shell with an initial fragment velocity of 6,180 f.p.s. has more than 2,500 effective fragments at a distance of 20 feet from the point of burst. The fragment distribution from HE projectiles also covers a greater area than shrapnel balls.

Casualties resulting from high velocity HE fragments sustain more severe wounds than do those resulting from the relatively low velocity shrapnel balls. In fact, shrapnel velocities were often so low that neither clothing nor skin penetration was effected within a few yards of the burst.

Though the application came in the latter part of World War II, the use of the radar proximity fuze materially enhanced the value of the HE projectile as an antipersonnel weapon. It insured the burst's occurring under optimum conditions for casualty production. This development undoubtedly points the way to the HE projectile's being used much more in the future as a specific antipersonnel weapon. Somewhat similar effects were noted in jungle warfare when fuzed projectiles were detonated by contact with the trees. In effect, this resulted in an airburst under optimum conditions.

A canister projectile was used in the 37 mm. gun at close ranges against tank personnel. The canister was loaded with 122 lead balls weighing approximately 100 grains each. Velocity was imparted to the balls by the 2,500 f.p.s. muzzle velocity of the canister. This load could only be effective at pointblank ranges where remaining velocities would be adequate. The canister was designed to release the balls immediately on firing, so rapid retardation of the balls could be anticipated because of the lack of desirable ballistic characteristics.

In artillery work, the only other projectiles usually used were the shot or AP loads and various chemical loads, such as flare and smoke. These loads have little significance as antipersonnel agents, casualties only being incidental to their primary purpose. Of course, some casualties result from direct hits by AP projectiles as well as by the secondary missiles resulting from their impact. In some phases of tank warfare, both can be major causes of tank casualties. Both also may be significant in naval warfare.

The Japanese still used some shrapnel of conventional design with their 75, 105, and 150 mm. guns. At near ranges in jungle fighting, shrapnel could have greater antipersonnel value as the remaining projectile velocity added to the initial velocity imparted to the shrapnel balls by the black powder bursting charge could make the balls effective missiles for a short distance. However, the usual muzzle velocity of Japanese artillery was low as compared with that common to modern weapons. It is apparent that the Japanese were either not cognizant of the value of velocity or were unable to produce weapons capable of sustaining the higher powder pressures necessary to secure the increased muzzle velocities.

The Germans had an interesting and effective antipersonnel 8 cm. HE mortar shell known as the "Bouncing Betty." On impact, a nondelay fuze ignited a smokeless powder charge which in turn ignited a delay pellet. The explosion of the smokeless powder charge sheared off pins holding the nose cap to the projectile body and threw the shell from 5 to 10 feet into the air. In the meantime, through the action of the delay pellet and a booster charge, the main TNT bursting charge was detonated at approximately the moment the projectile was at the height of its bounce. This was a simple means to obtain the effect of an airburst. Initial fragment velocities with TNT of approximately 3,500–4,000 f.p.s. resulted in effective fragment distribution for a considerable range.

Aerial Bombs [4]

Though World War I saw the first application of the airplane to warfare, it remained for World War II to demonstrate its use as a formidable military weapon. Personnel were attacked in one of two ways: By gunfire in strafing or by aerial bombs.

Missile casualties due to strafing have characteristics typical of small arms injuries except for several possible details. The speed of the airplane can add to wound severity by augmenting the bullet velocity by as much as 800 feet per second. Some casualties may also be due to tracer, AP, explosive, or other special bullets commonly used in airplane weapons. Another important factor is excessive yaw, as many gun barrels are in such a condition that the bullets are not stabilized. In rapid fire, the generated heat also expands the barrel to such an extent that the bullet may not follow the rifling.

Peculiar to the airplane as an antipersonnel weapon is the aerial bomb. While bombs are used for many other purposes, the fragmentation bombs are designed particularly for antipersonnel use. They are so constructed that on detonation there will be a spray of effective fragments capable of producing casualties over a considerable area. These antipersonnel bombs come in several sizes, ranging in weight from 20 to 260 pounds each.

Fragmentation bombs are somewhat similar to HE projectiles in that the bursting charge constitutes approximately 10 percent of the weight of the bomb. However, the bomb is specially constructed to yield a greater number of effective fragments. Fragment size is roughly controlled by design and construction.

At 100 feet from the point of burst, the 20-pound fragmentation bomb averages 829 effective fragments; the 90-pound bomb, 2,880; and the 260-pound bomb, 5,450 effective fragments. Because of the bomb design and the ratio of bursting charge to bomb weight, fragments are fairly large and at 100 feet from the point of burst have velocities of a little more than 1,000 feet per second.

The smaller 20-pound fragmentation bombs are commonly dropped in clusters of six bombs so that a salvo effect is obtained. A single plane may simultaneously drop a number of clusters. Planes in a group may drop their bombs all at about the same time, so that a considerable area can be blanketed with effective fragments. Many casualties are certain to result among exposed personnel. Small bombs dropped simultaneously in groups are more effective than a single bomb of the same weight.

Other bombs, though not designated for antipersonnel purposes, can cause missile casualties. The general-purpose type, usually with a bursting charge approximately one-half of the bomb's weight, is often used under conditions in which personnel will be exposed. As an example of performance, the 100-pound general-purpose bomb has 3,310 effective fragments at a distance of 100 feet from the burst moving at a velocity of 1,870 feet per second. The higher velocity makes fragments of a smaller size more effective than would be true

[4] Terminal Ballistic Data, Office of the Chief of Ordnance, Washington, D.C., 1944-45, vols. I, II, and III.

with the fragmentation bomb. However, this bomb has a much greater blast effect and depends largely on that effect in accomplishing its primary mission.

In some of the very large light-case bombs, the detonating charge accounts for 75 percent of the bomb's weight. These bombs, designed particularly for demolition work, accomplish their mission almost entirely through the blast effect. There also are other special-purpose bombs, such as AP, flare, and flashlight. The Germans had an AP bomb which was equipped with auxiliary rocket propulsion to give acceleration to aid in penetration.

Fragment distribution from a bombburst is fairly symmetrical with respect to the longitudinal axis. When a bomb drops with its axis vertical and detonates on contact, fragments fly in all directions. However, most bombs actually fall with their axis at such an angle to the perpendicular that there is considerable asymmetry in actual fragment distribution. The most dangerous sector is that from which the bomb's axis is leaning on detonation. On the opposite side from the burst, effective fragment range is much less.

Bomb detonation is effected through the action of a fuze which is armed when the bomb is dropped from a plane or shortly thereafter by the action of a wind vane. Fuzes are of two basic types—instantaneous contact or delayed action. Delay may be a small fraction of a second, or it may be some definite longer interval. Time fuzes similar to those used with artillery projectiles are only used with aerial bombs carrying flares or flash powder for night photography. It has not been practical to initiate airbursts through the use of time fuzes as time of flight is not sufficiently constant.

Though contact fuzes are designed to function instantaneously, there is, in fact, some time lapse between initiation of the primer and detonation of the bursting charge. In this interval, a bomb may penetrate the earth to such an extent that much of the force of the explosion is expended against the earth and upward. The earth acts in a degree to protect personnel. In the case of firm or impacted earth, the bomb may also disintergrate on impact so as to fail to function.

Obviously, for antipersonnel purposes, optimum results can only be expected from an accurately controlled airburst over exposed personnel. Application of the proximity fuze to the aerial bomb may accomplish this. However, in World War II, the most effective antipersonnel bomb was either the properly designed fragmentation-type or the general-purpose bomb, each neither so large nor so heavy that dampening earth penetration would occur before detonation. Under some conditions, small bombs lowered by parachutes to delay the descent were found to be particularly effective as antipersonnel weapons against personnel in the open or in foxholes.

Hand and Rifle Grenades

Most hand grenades are primarily offensive weapons of the fragmentation type. Some have fairly thick cast iron walls divided into serrated segments and others have comparatively thin steel casings. The Germans used one

offensive hand grenade which consisted of a pressed disk of explosive RDX (cyclonite) and wax with a fuze inserted in a hole in the side of the disk. This grenade depended on blast effect alone for performance.

One of the cast iron, fragmentation-type hand grenades loaded with TNT as a bursting charge had 254 effective fragments with an impact velocity of nearly 2,000 f.p.s. at 20 feet from the point of burst. Many of the fragments had sharp, serrated edges and at impact velocities of nearly 2,000 f.p.s. would produce severe wounds. However, velocity was rapidly retarded so that effective range was not great.

Grenades are of various shapes, some for direct throwing, while others of the so-called potato-masher type have a wooden handle to aid in hurling. Rifle grenades are similar to hand grenades, except that they are launched by means of a rifle and consequently have greater range. Some special grenades, hand and rifle, of the AP hollow-charge type were developed for AT use. Their value as missile-casualty agents is quite secondary.

Grenades can only be thrown or propelled to a limited range, so usefulness is restricted to certain conditions. While the range must be such as not to endanger friendly troops with resultant fragments, it also must permit of reasonably accurate throwing. Grenades are particularly effective when tossed into a pillbox or thrown into an occupied dugout. In World War I, hand grenades were especially useful in clearing trench bays. When fragmentation grenades detonated in close groups of personnel, casualties with severe, multiple wounds resulted.

The Japanese had a hand grenade made of terra cotta. It was charged with 3½ ounces of explosive which would burst the terra cotta container into fragments dangerous at near ranges. Many of the Japanese grenades were odd, in that the fuze mechanism had to be armed by a sharp blow before hurling. After arming, there was a 4- to 5-second delay pending detonation.

Many hand grenades were used for the preparation of boobytraps. Once armed, grenades are sensitive and make a dangerous boobytrap which cannot be easily unarmed. Severe wounds can be expected, as the victim is usually close to the explosion, where many high-velocity fragments and secondary missiles will be the rule.

Landmines

Landmines are of two categories—AT and antipersonnel. The former usually requires so much weight to initiate the primer that it is of little direct interest as a casualty-producing agent. On the other hand, the sensitively fuzed antipersonnel mine is highly effective and is often responsible for many and severe casualties.

Basically, the landmine is a defensive or protective weapon, hence more likely to inflict casualties on an advancing force. The antipersonnel mine also quickly exacts its toll of the careless or inexperienced soldier. It may be

equally dangerous to friend or foe, especially when the soldier is careless and disregards warning signs of a minefield intended to protect a bivouac or beachhead.

Mines commonly inflict severe wounds as the victim is usually very close to the detonation, often standing directly over the mine. Many lower extremity casualties can be expected. When individuals are advancing in close formation, a single mine can be responsible for multiple, severe casualties. Many mines not only have a considerable immediate range but often are so sensitive as to be detonated by neighboring detonations, so that the tripping of a single mine may fire one or more in the near vicinity.

Though landmines of various types have been used in warfare almost since the inception of gunpowder, before World War I they were crude improvisations. Most were comparatively ineffective. In World War I, the tank and armored vehicle on one hand and the hand grenade on the other hand naturally led to the development of the boobytrap and antivehicle and antipersonnel mine. This development was greatly favored through the use of TNT, a powerful but at the same time a comparatively safe explosive to handle.

Modern production methods as well as modern explosives made wholesale use of landmines both practicable and effective in World War II. Boobytrapping was developed to a new high, with grenades or antipersonnel mines commonly providing the effective part of the boobytrap. Any soldier could handle deadly TNT with impunity until it was set in place and sensitively fuzed.

Antipersonnel landmines commonly carry a charge of a pound or less of TNT or similar explosive and are generally no more than 4 to 5 inches in their greatest dimension. They may be detonated by the direct pressure of 15 to 40 pounds or by a few pounds pull on an apparently innocuous trip wire. Early in the war, mines usually were in metallic containers, but with the development of magnetic mine detectors many were made of glass, earthenware, or plastic to prevent detection.

Early types depended on the fragmentation of the mine container and component parts together with secondary missiles of sand, pebbles, and dirt for their effectiveness. Later, mines were developed which bounced from 6 to 7 feet into the air before the main detonation occurred, thereby effecting an airburst making the fragmentation effective over a much greater area. The Germans developed several mines of this type which also carried shrapnel balls to add to the missiles of normal casing fragmentation. One of these mines had 350 steel balls weighing approximately 53 grains each. This shrapnel filling propelled by 8 to 16 ounces of TNT had an effective range of 150 to 200 yards. There also was a very effective wooden box German antipersonnel mine which did not activate the magnetic mine detectors. This mine was simple and cheap to construct. It also was constructed in a larger size for AT use.

Blast [5]

The hot gases ejected by a detonating bomb sweep out and compress the surrounding air and throw that compressed body of air against adjacent layers of air. In this way, a belt is formed within which the air has high pressure and high outward velocity. This belt is limited by an extremely sharp front (less than one-thousandth of an inch) called the shock front in which the pressure rises abruptly.

The shock front travels away from the point of detonation with an extremely high initial velocity (3,000 f.p.s. at 60 feet from a 4,000-pound light-case bomb where the pressure jump is 100 pounds per square inch). The velocity then decreases rapidly towards the velocity of sound (about 1,100 f.p.s.) as the shock front travels on and the pressure jump decreases.

For a better appreciation of the comparable velocity of the blast wave, it is well to consider some of the better-recognized air velocities encountered in winds and storms. Winds of 50–60 miles per hour are classified as gales, and in hurricanes wind velocities of 80 miles per hour are common with now and then velocities in excess of 100 miles an hour being reported. Wind velocities in tornadoes have not been accurately recorded but are judged to be of the order of 200–300 miles per hour. The fact that tornadic winds often blow straws into tree trunks is well established in weather bureau documents. The highest wind recorded by a weather bureau was slightly more than 230 miles an hour at the top of Mount Washington, N.H. Though the blast wave travels at a velocity of 4,000 f.p.s. or more when initiated, it quickly damps down to the velocity of sound in air. This is approximately 1,100 f.p.s., the equivalent of 750 miles per hour. It is due only to their very short duration that blast waves are not far more destructive than they are in fact.

The excess pressure prevailing at a point in the air after the arrival of the shock front decreases and vanishes in a short time (about 0.04 second at 400 feet from a 4,000-pound light-case bomb; about 0.006 second at 50 feet from a 100-pound general-purpose bomb) and is followed by minor disturbances which often include a partial vacuum. The entire disturbance produced in air by the detonation of a bomb is called blast.

Peak pressure.—The peak pressure—the highest excess pressure which is attained right at the shock front—gives a measurement of the maximum force exerted against a structure by the blast (pressure $\times$ area $=$ force).

Effects of confinements.—The presence of obstacles which prevent the travel of blast in some directions may increase the effect of blast in other directions.

A blast traveling along a tunnel, a corridor, a trench, and, in the case of large bombs, even along a street is effectively confined, so that its intensity decreases much more slowly than in the open.

When a bomb detonates inside a house, demolition of the walls may occur even if the distance from the point of detonation to the walls exceeds the

[5] See footnote 4, p. 100.

radius of damage for the same type of bomb bursting in the open. This is due to a variety of effects, among which is the "multiple punch" effect created by the blasts' hitting on a wall in quick succession after having been reflected by other walls. If the effect of blast is intensified on one side of a wall by its confining action, it is reduced by the same token on the opposite side of the wall by its screening action.

Protection from blast.—A wall effectively reduces blast pressure and impulses on objects close to it if it is about 10 feet by 10 feet or larger and if it is of sufficient strength to withstand the blast.

Foxholes, slit trenches, or ditches reduce the blast pressure by about 50 percent. A system of four right angles reduces it to about 15 percent.

Position of the body can have a considerable influence in protection from blast effects. Lying prone on the ground will often materially lessen direct blast effects because of the protective defilade effects of irregularities in the ground surface. Ground also tends to deflect some of the blast forces upward. Standing close to a wall, even on the side from which the blast is coming, also lessens some of the effect.

Many of the persons said to have been injured by blast were actually injured through the secondary effect of being knocked down and forcibly coming in contact with the earth or with other hard objects. If the head of a person thrown down comes in contact with a stone or similar hard object, injury may be quite severe. Any lessening of the distance through which one falls will lessen the probable degree of injury.

Orientation of the body also affects severity of the effect of blast. Anterior exposure of the body may result in lung injury, lateral position may result in more damage to one ear than the other, while minimal effects are to be anticipated with the posterior surface of the body toward the source of the blast. Defilade and reflection of the blast from the body itself may have some effect.

Blast pressure and the orientation of an object.—At a distance of 20 feet from the point of detonation, the peak pressure on a wall parallel to the direction of travel of the blast wave is only about one-seventh of the pressure measured on a similar wall placed at right angles to the direction of travel of the blast. This factor varies with distance, and at 200 feet from the point of detonation the ratio is about 1 : 2. Pressures on oblique surfaces vary accordingly.

The effects of peak pressures (table 18) follow:

At peak pressures of 500 pounds to the square inch, 50 percent killed.

At peak pressures of from 60 to 100 pounds to the square inch, 50 percent seriously injured.

At peak pressures of 15 pounds to the square inch, eardrums ruptured.

At the nearest point, peak pressures would be between seven and eight times greater on an object oriented at right angles to the travel of the shock wave; at a distance of 90 feet, the factor would be approximately four; and at 150 feet, about three.

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TABLE 18.—*Peak pressures in pounds per square inch at varying distances from point of detonation for general-purpose bombs of various weights on a surface parallel to direction of travel of shock wave*

General-purpose bomb	Pressure at—					
	30 feet	60 feet	90 feet	120 feet	150 feet	180 feet
Pounds						
100	17	4	------	------	------	------
500	80	6	3	------	------	------
1, 000	200	20	7	4	------	------
2, 000	400	50	13	7	4. 5	------
4, 000	1, 000	170	40	16	10	7

Blast alone may cause serious injury or death at distances from 120 feet for the 4,000-pound light-case bomb to less than 60 feet for the 100-pound general-purpose bomb. However, it also is more than likely that within such ranges bomb fragments or secondary missiles will be responsible for injury.

Secondary Missiles

For this discussion, a secondary missile will be considered to be a missile which has been set into motion by another or primary missile and which has traveled for an appreciable distance in the air or more mediums before causing a casualty. This eliminates body-armor fragments, pieces of clothing, and other articles on the person from consideration as secondary missiles at this time. Fragments of bone or other tissues may be secondary missiles under certain conditions.

Many wounds are produced by secondary missiles given their velocity by the blast of the primary bomb, mine, or projectile. Bullets may strike dry sand, rock, or other material which may be moved or broken and thereby set into motion secondary missiles capable of producing a wound. Such wounds may be comparatively trivial but painful and may be fully capable of rendering a man a noncombatant for some time. A face peppered with sand can be quite bloody and painful, though actual injury is but skin deep.

Secondary missiles probably produce more casualties than all other causes combined in the aerial bombing of the unprotected civilian city habitations. Flying glass is particularly bad, even at a considerable distance from the source of the blast. Two factors make glass particularly bad: First, it is easily broken; and, second, the fragments are usually of a shape and type which will readily penetrate the flesh.

The landmine probably attains its maximum antipersonnel qualities from the many high-velocity secondary missiles of sand, dirt fragments, and other materials immediately over the mine. The way it is planted and detonated

is designed to make the most of the secondary missile as a casualty-producing agent. High-velocity propellents are commonly used in mines; the case holding the propellent is comparatively light; and the detonation occurs close to the victim, often within a few inches or at most only a foot or so. Impact velocities are certain to be high.

Light secondary missiles may have high velocities, approaching the maximum possible with any given propellent. Heavier missiles have correspondingly lower velocities. Under certain conditions, for instance, a rifle bullet can spall out a fragment of armor and in so doing impart to the spall a velocity greater than 50 percent of the bullet's impact velocity. Such a spall may produce a more serious wound than the original bullet, because of its size and sharp, irregular edges.

In the immediate vicinity of a bomb or shell detonation, large objects, such as bricks and stones, may be set in motion as secondary missiles. Initial velocities as a rule are not so great, but their greater mass gives them a considerable danger range. Lighter fragments lose velocity more rapidly.

When metal objects, such as nails, screws, and nuts, are set in motion as secondary missiles, they can produce serious wounds. Such objects have been used in artillery projectiles as well as in the older types of landmines (fougasse). Retardation is a function of sectional density (A/M) (p. 121) and, in general, the greater the density of material the longer it will remain dangerous because of impact velocity.

Secondary missiles may be important also in connection with the detonation of HE artillery projectiles, though normally not to the same degree as in the case of aerial bombs, as the detonating charge is comparatively smaller. The projectile design also favors the production of projectile fragments, which generally range farther and are a much more potent factor as a casualty producer than the secondary missile.

Probability of a Missile Casualty

From time to time, the ordnance engineer asks the military surgeon for an opinion on the probable effectiveness of a proposed antipersonnel agent in producing effective casualties. The ordnance engineer is also seeking a mathematical expression which will permit a calculation of the probable effectiveness of a given antipersonnel agent.

The designer of a shell or bomb can usually predetermine the probable fragment size, velocity, and average distribution. He has also adopted an arbitrary criterion of 58 ft.-lb. of kinetic energy as determining a fragment which is capable of producing a casualty. However, he lacks mathematical information as to human body vulnerability and is commonly unable to predicate very accurately the battlefield performance of a given agent.

Some research and analysis has been attempted to bridge this important gap of equal interest to the ordnance designer and military surgeon. So far, the arbitrary criterion of 58 ft.-lb. of energy for an effective wound-producing

missile has proved to be reasonable. It provides a basis upon which the relative effectiveness of antipersonnel agents may be compared.

Before absolute predictions are possible, however, much more must be known about the target. What is the target area? What proportion of that area is actually incapacitatingly vulnerable to an effective missile?

Target area is variable due to body presentation. Black, Burns, and Zuckerman,[6] in England, calculated the average projected area of the full standing figure as follows:

Region:	Percent	Square feet
Head and neck	12	0.50
Thorax	16	.67
Abdomen	11	.46
Upper limbs	22	.92
Lower limbs	39	1.65
Total	100	4.20

This projected area can vary and can be reduced to a much smaller amount as the figure turns sidewise, kneels, or lies prone. The kneeling position presents approximately 55 percent of the full figure, sidewise some 45–50 percent, and the end-on prone figure less than 25 percent of the full figure.

After determining the area of presentation, the question of incapacitating vulnerability must be determined, as many wounds in the total body area will not necessarily incapacitate a soldier. There is some difference of opinion as to the proportion of this incapacitating vulnerable area. Zukerman and coworkers considered that some 10 to 15 percent of the projected area represented the projection of vital organs. They also concluded that the effective vulnerable area to small high-velocity fragments was 2.83 square feet or 67 percent of the total area. McMillen and Gregg,[7] in an independent approach to the problem through anatomical analysis, found the projected incapacitating vulnerable area of the full, standing figure as follows:

Region:	Vulnerable anterior projection area as percent of total body area
Head and neck	3.5
Trunk	26.0
Arms	4.5
Legs	9.0
Total	43.0

Relative percent of vulnerable area also varies to a marked degree with the position of the figure. For instance, in the prone figure, head on toward the missile source, at least 75 percent of the presented area is vulnerable.

[6] Black, A. N., Burns, B. D., and Zuckerman, S.: Experimental Study of the Wounding Mechanism of High Velocity Missiles. Brit. M.J. 2: 872–874, 1941.

[7] McMillen, J. H., and Gregg, J. R.: The Energy, Mass and Velocity Which is Required of Small Missiles in Order to Produce a Casualty. National Research Council, Division of Medical Sciences, Office of Scientific Research and Development, Missile Casualties Report No. 12, 6 Nov. 1945.

Another potent variable is the angle of incidence of the missile with respect to the target area. For instance, a missile striking the thorax at a low angle of incidence will often produce a superficial wound, while one striking more nearly at a right angle to the target will penetrate and produce a severe wound or fatal casualty. The first may not immediately materially impair the soldier's fighting ability nor require any prolonged hospitalization or treatment. The severe wound could, on the other hand, permanently remove the soldier from the fighting forces.

While the extremities account for less than one-third of the projected vulnerable area, casualty statistics commonly ascribe well over one-half of the casualties and resultant time lost to the service to extremity injuries. This in part is attributed to the fact that fractures are more common in the extremities and that fractures are injuries which definitely require immediate as well as prolonged treatment.

This apparent bias in wound distribution may be influenced by several factors. First, available casualty statistics are based on a study of the wounded rather than the wounded and the killed. It is well established that much data based on the killed are quite erroneous.

Another variable and unknown factor which could materially affect casualty statistics interpreted on the premise of random distribution of missiles is the degree of earth penetration effected by a projectile or bomb before detonation. Any penetration will result in some defilade effect and in turn affect the purely random distribution of fragments. There usually is some penetration and in soft earth it may be considerable before the bursting charge actually functions. Where there is penetration, fragments are naturally deflected upward by the earth surrounding the projectile. This results in some increase in fragment density in the lower zones, while the earth surface will be protected from fragments by the defilade effect of the earth immediately surrounding the projectile.

Personnel in the immediate vicinity of the burst will be subjected to a shower of high-velocity fragments from the knee level up. Many fragments will be capable of producing severe wounds. Those hitting the extremities will often cause severe fractures, while the same fragment striking a vital area in the soft tissues will frequently result in a fatality. In general, extremity injuries are not so fatal as those in the body or head areas.

Study of detailed statistics supports this approach to the problem of apparent bias in casualty statistics. There is an increasing number of fractures upward from the ground—more in the upper than in the lower extremities, though the area of presentation of the upper is less than that of the lower extremities. Fractures below the knee are definitely fewer than those above that point, indicating a fairly definite defilade effect as just predicated.

Though there would often be fractures in the case of the killed in action, it is known that only too often the statistical studies fail to record them with the cause of death being ascribed to another more apparently fatal effect.

Another factor in World War I fighting which could have materially influenced the wound distribution and statistical studies was the machinegun. In many sectors, it was the practice to defend areas by cones of machinegun fire close to the ground level. Leg injuries would be more common than all others combined under such circumstances.

Fragment-damage tables,[8] published by the Office of the Chief of Ordnance, give the average distribution of effective fragments at various distances from the point of burst. With such tables, the distance at which a soldier has a given chance of being hit may be calculated. For example, a soldier is required to take a 1 to 100 chance of being hit by a fragment from a 20-pound fragmentation bomb. Suppose that the soldier is on open terrain in such a position that a 2-square-foot area of his body is exposed to fragments coming directly from the bomb. Under these circumstances, the effective fragments per square foot to which the soldier is exposed are $\frac{1}{100}$ x $\frac{1}{2}$ equals 0.005 per square foot. From the fragment-damage table for that bomb, it is found that the soldier should be about 150 feet from the bombburst. In the case of the 260-pound fragmentation bomb, he should be not less than 300 feet from the burst. Under similar conditions, the danger zone for a 75 mm. HE shell is approximately 100 feet and for the 105 mm. shell between 100 and 150 feet.

Depending on the orientation of the bomb or projectile at time of burst, effective fragment distribution varies considerably from the average on which the cited example is based. Effect of penetration before burst also is disregarded. In the most dangerous sector, fragment density may be increased as much as six times the average, increasing the danger zone severalfold. On the other hand, in the less dangerous zones, the fragment density is materially decreased.

In general, the wound factor varies something more than the square of the distance from the point of burst. Retardation of fragment velocity reduces the number of effective fragments, while the density per unit area of exposure also is affected by the distance from the point of origin. Fragment distribution too is materially influenced when a shell or bomb penetrates the ground appreciably before detonation.

The probability of a missile casualty as well as the character of a missile casualty also can be expected to vary from offensive to defensive warfare. The offensive soldier is of necessity more exposed. He is forced to advance in the face of prepared zones of fire, mined areas, and various protective devices calculated to minimize the exposure of the defenders.

In advancing, the experienced soldier takes advantage of all possible cover. However, he has to look for his enemy, so he must more or less expose his head. If ranges are sufficiently close to permit aimed shots, a preponderance of head casualties can be expected. This should be especially true of jungle warfare.

[8] Terminal Ballistic Data, Office of Chief of Ordnance, Washington, D.C., 1945, vol. III.

The Casualty Criterion

Terminal ballistics and the missile casualty become of importance to the military surgeon when the ordnance engineer asks for an opinion on the probable value of any given missile in producing a casualty. The ordnance engineer also requires a significant yardstick which may be mathematically applied in developing his designs of bullets, bombs, shells, grenades, or other missile casualty-producing agents.

Technical advancement has too often demonstrated the validity of the theoretical approach in design problems to permit the older rule-of-thumb or trial-and-error methods to be used in working up the instruments of modern warfare. Knowing the metal and detonating charge to be used in a given bomb, the ordnance engineer can readily calculate the number of fragments as well as their size and weight with probable distribution and velocities at any given distance from the point of burst. However, a criterion as to probable effectiveness is necessary if the data just cited are to be applied to practical design. During World War II, a criterion of a missile with weight and velocity sufficient to give it 58 ft.-lb. of kinetic energy was used in practice.

Though the adoption of the 58 ft.-lb. figure was arbitrary or empirical, it was much more practical than using the penetration of pine boards or other inanimate objects for the purpose. Selection of the figure was in a measure substantiated by the work of Gurney.[9] This figure also was subsequently reasonably substantiated by the research of Harvey and his associates. It did supply a fully comparable yardstick on which to base theoretically relative efficiency.

A criterion of the potential wounding possibilities of a missile was first brought to the fore in the late 1920's when bullets of various calibers were under consideration in the development of a semiautomatic weapon. When this problem was presented to the U.S. Army Medical Department, it quickly became apparent that not only was there no criterion but that the military surgeon knew little, if anything, regarding the physical laws underlying the mechanics of wound formation or the production of a casualty.

For many years, ordnance engineers had been using the penetration of 1-inch pine boards separated by a small air space (1 inch) for judging the relative efficiency of bullets. Subsequent investigation revealed this test to be far from precise because of variations in pine boards, as well as many other factors beyond reasonable control. The motions of a spinning missile vary greatly as it passes through mediums of different densities or are modified by other variable physical characteristics. This greatly influences the retardation of the bullet and resultant conditions under which its kinetic energy is given up in the retarding material and influences the physical nature of the wound to a considerable degree.

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[9] Gurney, R. W.: A New Casualty Criterion. Ballistic Research Laboratory Report No. 498, Aberdeen Proving Ground, Md., 31 Oct. 1944.

Kinetic energy is computed from the formula $mv^2/2$, in which m is the mass and v the velocity. It is noted that velocity plays much the greater part. If it is borne in mind that the usual bullet employed in military use varies in weight from around 135 to something more than 200 grains, the following tabulation showing the weight of missile necessary at various velocities to produce a kinetic energy of 58 ft.-lb. is of interest:

Velocity of missile	Weight of missile	Velocity of missile	Weight of missile
F.p.s.	*Grains*	*F.p.s.*	*Grains*
500	104.0	4,500	1.3
1,000	26.1	5,000	1.0
1,500	11.6	5,500	.9
2,000	6.5	6,000	.7
2,500	4.2	6,500	.6
3,000	2.9	7,000	.53
3,500	2.1	7,500	.46
4,000	1.6		

The fallacy of the pine-board penetration as a criterion of missile effectiveness was strikingly demonstrated quite accidentally when a shrapnel projectile was detonated in a close group of observers. The only real casualty was the man holding the projectile for he lost a couple of fingers from one hand. The shrapnel balls were well sprayed amongst the group of observers at close range and, yet, only a few black and blue places resulted—without penetration of the clothing. This total inefficiency of shrapnel was further demonstrated by study of known battlefield occurrences. However, shrapnel balls had penetrated many pine boards in the usual tests. Needless to say, the manufacture and use of shrapnel was promptly discontinued. In passing, it is also interesting to note that there is evidence of few true shrapnel wounds in World War I in which many tons of shrapnel were used. So-called shrapnel wounds on investigation were usually found to be due to HE missile fragments (table 19).

Distribution of Effective Missiles

In discussing the probability of a missile casualty, reference was made to fragment-damage tables. These tables are based on the assumption that a projectile or bomb breaks into a certain number of effective fragments and that the fragments are evenly distributed in all directions. In reality, this assumption is quite fallacious.

There is a marked variation in fragment distribution, even in the airburst. Sidewall fragmentation is quite different in character from that of base or nose fragmentation. Even in the light-case "blockbuster" bomb, there are differences in sidewall and nose or base fragmentation because of the relative thickness and distribution of the metal of the bomb. There also are fragments of

the fuze mechanism to be considered as these pieces are usually heavier and larger than wall fragments. They consequently have a greater danger range, and, while initial velocity may be slightly less, remaining velocity is better sustained because of greater mass.

TABLE 19.—*Weights, velocities, and distribution of effective fragments from various aerial bombs and artillery projectiles, showing variations to be expected*

Source of fragment	Distance from burst	Initial fragment velocity	Total effective fragments	Fragments per square feet	Lightest effective fragments	
					Weight	Velocity
	Feet	*F.p.s.*	*Number*	*Number*	*Grains*	*F.p.s.*
Aerial bombs:						
20 pounds	80	2, 810	895	0. 0183	18. 4	1, 190
	200		576	. 0019	48. 6	731
90 pounds	80	3, 100	3, 490	. 0712	15. 8	1, 280
	200		1, 770	. 0058	45. 9	753
100 pounds	80	7, 320	3, 943	. 0804	4. 8	2, 320
	200		1, 880	. 0061	27. 1	980
500 pounds	80	7, 390	13, 450	. 274	5. 3	2, 230
	200		6, 100	. 0199	26. 7	990
Artillery projectiles:						
3-inch HE shell	80	2, 260	370	. 0046	29. 3	943
	200		244	. 0005	59. 9	660
90 mm. HE shell	80	2, 900	427	. 0053	24. 1	1, 040
	200		319	. 0006	52. 5	705
81 mm. HE shell	80	3, 930	459	. 0057	16. 6	1, 250
	200		169	. 0003	45. 5	758
81 mm. HE shell	80	6, 180	614	. 0076	9. 2	1, 680
	200		112	. 0002	35. 0	862
4.5-inch HE rocket shell:						
Nose section	80	3, 500	152	. 0057	18. 8	1, 180
	200		93	. 0006	47. 7	738
Base section	80	4, 000	353	. 0104	17. 5	1, 220
	200		207	. 0010	45. 5	758

Source: Terminal Ballistic Data, Office of Chief of Ordnance, Washington, D.C., 1945, vol. III.

Fragmentation bombs are specially designed to produce the greatest number of effective fragments in the sidewalls. Such bombs usually strike in a more or less nosedown position, so that nose fragments are necessarily forced into the ground. Tail fragments commonly fly up into the air and in falling are impelled only by the force of gravity so that their velocity is insufficient to produce more than minor casualties.

In the HE shells, both the base and the nose of the projectile are definitely thicker than the sidewalls. Sidewalls produce many more high-velocity fragments than either the base or nose. However, base and nose fragments, being larger, are less retarded in flight and have a correspondingly greater danger

range. Density of fragment distribution from the nose or base is less than in the case of sidewall fragments.

Rocket projectiles present another anomalous situation. Depending on the type of rocket, these projectiles have a velocity of 400 to 800 feet per second. They are fuzed with supersensitive fuzes so that they commonly detonate in the air, and the remaining velocity of the rocket affects the fragment velocities. This results in a distinct butterfly pattern of fragment distribution. The rocket sidewall section bursts into more than twice as many effective fragments as compared with the nose in the 4.5-inch HE rocket shell. At 20 feet from the burst, fragment velocities vary from 2,440 to 2,570 feet per second.

Fragment-damage patterns are published by the Office of the Chief of Ordnance. These show fragment distribution presupposing a graze or airburst close to the ground surface with a particular orientation of the projectile. Even under these ideal conditions, most damage patterns are of a distinct butterfly type. In some directions from the burst, there may be very few fragments, while in other directions there may be many effective fragments of a mass capable of maintaining a dangerous velocity over a considerable distance.

There is no allowance in the fragment-damage patterns for any earth penetration by the projectile or bomb before detonation. However, in almost every case, more or less penetration occurs, which materially modifies the damage pattern. In the case of large HE projectiles, there usually is so much penetration that almost all of the energy of detonation is expended in cratering the earth. Soldiers often expressed little fear for these larger shells as their antipersonnel effect was essentially nil, barring a direct hit.

With the usual contact fuze and even with the superquick contact type, there is sufficient delay in firing the bursting charge to permit considerable penetration, especially into soft earth. Standard-type fuzes operate progressively through primer and booster to fire the detonating charge. Some time interval is required to initiate a primer which in turn initiates the booster which fires the main charge. During the delay, the projectile or bomb can effect some penetration. For that matter, it also requires appreciable time for the main charge to rupture the holding case and set the fragments into motion. Slow-motion pictures readily demonstrate an appreciable timelag before fragments are flying freely accelerated to their maximum velocity. Case rupture takes place in a progressive manner requiring a lapse of time for its accomplishment.

Used only during the latter days of World War II, the proximity fuze appears to make possible the accurately controlled airburst of artillery projectiles and perhaps aerial bombs. This application insures an airburst with a much wider distribution of effective fragments. It can be expected that distribution will also follow a much more random pattern under these circumstances. This type of burst obviates the loss of effective fragments through "cratering" or the defilade effect of earth penetration.

PHYSICAL ASPECTS OF THE MISSILE

Missile Velocity

Motion of translation, velocity, is the only factor common to all missles. It is probably the most important single factor in consideration of the missle as a potential casualty-producing agent. It is the major factor in making the missile capable of producing a wound.

For simplicity in discussion, velocities of less than 1,200 f.p.s. will be considered as low; those from 1,200 to 2,500 f.p.s., as medium; and velocities in excess of 2,500 f.p.s., as high.

Velocity is a continuously varying factor, and for ease in consideration as a function of the missile several phases of the missile trajectory will be discussed. First, the *initial* or muzzle velocity; second, the *impact* velocity or the speed of translation at the time the missile strikes a target; and third, the *remaining* (residual) or that velocity with which a missile leaves a target through which it has passed. In considering the missile and the production of a casualty, the second and third types of velocity are the more important. The impact velocity commonly determines the probable severity of a wound, while the difference between the impact and residual velocity determines the amount of energy doing work in producing the casualty. Initial velocity is important in that it insures an adequate impact velocity at the time a missile reaches the target. It also determines the probable danger range.

Initial velocity.—Initial velocity of a missile may be anything from a few feet a second up to much more than a mile a second. Small arms missiles have muzzle velocities ranging from around 800 up to approximately 3,000 f.p.s. Some of the recently developed AT weapons have muzzle velocities of slightly more than 5,000 f.p.s. Bomb fragments may have initial velocities of more than 7,000 f.p.s., and some of the fragments from HE artillery projectiles approach this initial velocity. Some artillery projectiles are launched with muzzle velocities greater than 3,000 f.p.s., though most have muzzle velocities between 2,500 and 3,000 f.p.s. The 21 cm. K12 German gun was credited with a muzzle velocity of 5,330 f.p.s. and a range in excess of 70 miles.[10]

In the antipersonnel weapon group, most sidearms, including the comparatively new carbines and small automatic weapons, launch bullets with muzzle velocities in the low-velocity category. On the other hand, most military rifles fire ammunition with muzzle velocities from 2,400 to 2,800 f.p.s. The older Japanese 6.5 mm. rifle fired ball ammunition with a muzzle velocity of 2,400 f.p.s., while most of the U.S. rifles and those of the Germans used ammunition with muzzle velocities near 2,700 feet per second.

Investigations in the late twenties and early thirties demonstrated the effectiveness of higher velocity missiles in the penetration of armor and led to

[10] Catalogue of Enemy Ordnance Materiel, Office of the Chief of Ordnance, Washington, D.C., 1945, vol. I (German), p. 100.1.

AT weapons of small caliber with velocities ranging from somewhat more than 3,000 up to more than 5,000 f.p.s. The soldier's inability to withstand more than a certain amount of recoil coupled with excessive barrel erosion accompanying the higher velocities operated to prevent the development of military weapons of the sidearm or shoulder type in this category for routine use.

High muzzle velocities in artillery weapons are seldom of more than didactic interest to the student of the missile casualty. Such velocities are usually for the purpose of increasing the effective artillery range, and at these excessive ranges the remaining projectile velocity is likely to be relatively low. Missiles from artillery projectiles attain their effective velocity more from the bursting charge in the projectile than from the motion imparted to the projectile in firing from the artillery piece. Suffice it to say that in general the higher the initial velocity of artillery ammunition, the more costly will be the gun that launches it. Such guns also have extremely short effective use periods without relining of the barrel, which is a major task.

Basically, most artillery has become primarily an antimateriel weapon with the antipersonnel characteristics only secondary factors. Of course, the exception to this is the target of massed men against which HE artillery projectiles are highly effective and their use militarily justified.

Initial or muzzle velocity is of interest only to the student of the missile casualty in that this velocity predetermines to a considerable degree the impact or effective velocity of the missile in producing the casualty. Once the accelerating force ceases to operate on a missile, deaccelerating forces take over, and the velocity is retarded. Retardation factors will be discussed later in more detail (p. 120). However, proximity to the missile source largely determines the impact velocity, and this in turn has much to do with the severity of the casualty. It is this proximity which makes the landmine a particularly vicious antipersonnel weapon. Velocities are high and missiles are many. The victim is often standing right over the mine or very close to it.

Impact velocity.—Of all factors to be considered in the missile casualty as a physical phenomenon, impact velocity is decidedly the most important. It determines the character of the wound and in turn only too often the fate of the victim. Research has demonstrated that a missile velocity of from 125 to possibly 170 f.p.s. is necessary to effect penetration of the human skin when using steel spheres one-sixteenth to one-fourth inch in diameter. Velocities of less than this produce only contusion without a break in the skin. Clothing also exerts a threshold penetration factor, at present undetermined. However, it is believed to be less than that of skin, which, comparatively speaking, is quite high. Of course, amount of clothing and its particular nature as well as other factors will affect the threshold velocity.

In the light of available information, few missiles with impact velocity of less than 200 f.p.s. are likely to cause more than a trivial wound in the clothed subject. Exceptions to this are the few missiles which may penetrate vital body cavities through apertures, or the more easily penetrated portions of the anatomy such as the eye.

The military surgeon is generally interested in missiles with impact velocities in excess of 200 or 250 f.p.s. In practice, it is probable that few wounds are caused by missiles with velocities much less than 500 f.p.s., and that most of the battlefield wounds are caused by missiles with velocities two and three times that figure. Some wounds are caused by missiles with impact velocities well above 2,500 f.p.s. High explosive shell fragments account for many wounds, and these velocities are apt to be well above 3,000 f.p.s. at near ranges. With the use of the proximity fuze in antipersonnel shells and aerial bombs, many missile casualties occur from fragments with velocities of 3,000 f.p.s. and upward.

With low-impact velocities, wounds are found to be relatively "cleaner" and free from the so-called explosive effect. With medium velocities, wounds are more extensive with considerable tissue destruction and with some explosive effects when conditions are favorable, High-impact velocities result in many so-called explosive wounds, with a maximum of tissue destruction.

Superhigh velocities make small missiles deadly. Comparatively, enormous tissue damage can result from the penetration of a very small fragment of a grain or so in weight when propelled at the supervelocities. In English bomb incidents, it was noted that minute missiles could be forced through the head with through-and-through wounds of the brain with slight, if any, visible evidence of a wound. The victims often walked away from the incident without even so much as a headache to show for the occurrence. It is known that the minute pins used by entomologists for the mounting of mosquitoes can be readily forced through a person's hand without evidence of blood or trauma and without sensation to the victim.

Remaining velocity.—Remaining velocity is of importance to the investigator in that it permits the determination of the kinetic energy expended in the production of the wound when a missile perforates a target. When a missile fails to pass through the target, all of the kinetic energy due to impact velocity is expended in wound formation. Apparently, the only fair measure of wound comparison on a physical basis is the expenditure of energy. Wounds cannot readily be compared on mere appearances alone, especially superficial appearances. In practice, remaining velocity can seldom be known, while in research it should always be measured or otherwise determined in some strictly comparable manner.

Momentum, Energy, Power

There has been much speculation and some observation as to the magnitude of the missile wound and its correlation with either the momentum, kinetic energy of the missile, or the rate with which energy does its work (power)—all physical attributes due to velocity. Momentum is a function of the mass times the velocity; energy a function of the mass times the square of the velocity; and the rate of doing work or power, a function of the mass times the cube of the velocity.

Before modern research, factual information on the various physical events actually occurring in the formation of a wound was lacking. Events transpire too quickly for the human senses to perceive the details. Earlier serious research studies had been inadequately instrumented to permit recognition of details. Results also were beclouded by the presence of indeterminate variables, such as deforming bullets, yaw, and other form factors.

To bring out and to evaluate fundamental postulates, basic research was conducted with nondeforming steel balls devoid of yaw or other complicated form factors. Simple mediums, such as water and 20 percent gelatin block tissue models, were used, as well as animal tissues. The cathode ray oscillograph and microsecond X-ray permitted the recording and accurate measurement of phenomena often completed in a few microseconds.

Results from this study were carefully analyzed, and it became apparent that all physical phenomena connected with the wound and its formation were direct functions of the kinetic energy doing work. Neither momentum nor the rate with which the energy did its work (power) could be correlated smoothly without excessive deviation with any of the various events which occur in the missile wound.

Hunters have entered into many acrimonious arguments on what constitutes an effective bullet in the taking of game. Here some claim that momentum is the factor. However, this opinion is believed to be due to the fact that hunters are continually observing the effects of bullets which usually deform seriously or more often break up on impact. In the latter case, the greater the mass, consequently the greater the momentum, the greater the apparent effectiveness of the bullet as it is less apt to disintegrate into such small pieces as to be almost useless after penetrating the hide of the animal. It is known experimentally that this last commonly occurs with the soft-nose hunting loads at impact velocities in excess of 2,000 feet per second.[11]

While velocity is the most important single factor in making the missile potent as a casualty producer, it attains that importance only through the fact that it gives the missile kinetic energy with which to produce the casualty. Physics recognizes two types of energy: Potential energy due to position and kinetic energy due to motion. The latter is computed from the formula $mv^2/2$ (p. 112). In the English system, m is in pounds and v in feet per second. The corresponding results are in absolute units (poundals) which may be converted to the more conventional foot pounds by dividing by the acceleration due to gravity, (g) or 32.2.

From the formula, it is noted that kinetic energy varies as the square of the velocity. In practice, this means that doubling the velocity multiplies available kinetic energy by four. The following tabulation gives the kinetic

[11] (1) Callender, G. R., and French, R. W.: Wound Ballistics: Studies in the Mechanism of Wound Production by Rifle Bullets. Mil. Surgeon 77: 177–201, October 1935. (2) Callender, G. R.: Wound Ballistics: Mechanism of Production of Wounds by Small Arms Bullets and Shell Fragments. War Med. 3: 337–350, 1943.

energy (ft.-lb.) at different velocities for a missile weighing 100 grains and readily demonstrates why small missiles become lethal at the higher velocities:

Velocity (F.p.s.)	*Energy (Ft.-lb.)*	*Velocity (F.p.s.)*	*Energy (Ft.-lb.)*
500	55	5,000	5, 545
1,000	222	6,000	7, 985
2,000	887	7,000	10, 868
3,000	1, 996	8,000	14, 196
4,000	3, 549		

Kinetic energy varies directly as the mass of the missile. Hence, weight is of much less importance than velocity. Doubling the weight only doubles the energy.

Most bullets used by the military vary in weight from around 150 to approximately 200 grains. The corresponding kinetic energy at the usual initial velocities is between 1,500 and 2,500 ft.-lb., while some distance from the point of launching with lower impact velocities kinetic energies are much less, usually well under 2,000 ft.-lb. and often less than 1,000 foot pounds.

Again considering the tabulation just presented, it can be readily seen that considering the 150–200 ft.-lb. necessary for skin penetration that, at impact velocities of 7,000 f.p.s., missiles of less than 2 grains in weight are potential casualty-producing agents. This fact makes the modern bomb and artillery HE shells potent antipersonnel agents. At close ranges, there are many fragments which weigh at least 2 grains and which have velocities of 7,000 f.p.s. or more with the newer propellents. Multiple severe wounds can be expected.

With impact velocities of 5,000 f.p.s., missiles must weigh nearly twice as much to have energy equivalent to those at the higher impact (7,000) velocity. However, compared to the usual military bullet, these are still very small fragments.

The mass-velocity relationship and kinetic energy makes the landmine a particularly vicious weapon in that fragment velocities are of the order of 5,000 f.p.s., and there are many secondary missiles in addition to the fragments of the mine itself flying about with these supervelocities. Multiple severe wounds are to be expected, especially when the victim trips the mine by walking on it. In addition, there is quite an area within which missiles have velocities in excess of 3,000 f.p.s., and small objects can continue to be serious casualty producers.

Hand grenades with initial fragment velocities of 2,900 f.p.s. produce many fragments of a weight sufficient to have adequate kinetic energy to produce a severe wound. Grenades also are able to start effective secondary missiles into motion.

In HE shellburst with initial fragment velocities often a little more than 6,000 f.p.s., severe wounds are the rule. These too can readily produce severe casualties at the closer ranges.

Even water can be a casualty-producing missile when propelled with sufficient velocity. One of the more efficient metal-cutting tools is simply a small stream of water under high pressure (supervelocity).

Drag, Retardation, Ballistic Coefficient

Retardation varies directly as the square of the velocity and as the diameter of the missile. It varies directly as the density of the retarding medium and inversely as the mass of the missile. These are the more important factors affecting the retardation of a missile. They also largely determine the amount of kinetic energy which is utilized in the production of a missile casualty.

While complicated in detail, pertinent facts and relationships can be gained from a study of the formulas regarding the missile motions which are applicable to the military surgeon's study of the missile as a casualty-producing agent, as well as the wound as a physical entity. The following basic formulas are presented:

Drag (D)

$$D = \rho d^2 v^2 f(v/a) \text{ or } D = K_D \rho d^2 v^2 \qquad (1)$$

in which ρ=density of the medium
d=diameter of projectile
$f(v/a)$=function v/a or K_D, the drag coefficient
where v/a=Mach number
v=velocity of projectile
a=velocity of sound in the medium

This formula applies particularly to motion in air and to missiles without particular ballistic shape, such as spheres.

For pointed projectiles the formula becomes

$$D = k\delta\rho d^2 v^2 f(v/a) \qquad (2)$$

$f(v/a)$ is the same for all shapes
k is a constant determined by shape
δ is a constant to allow for the effect of wobble, yaw, or other deviation from true flight.

Let $F(v) = v^2 f(v/a)$
$F(v)$=function v
M=mass
C=ballistic coefficient (ability of a projectile to overcome air resistance)

then

$$C = \frac{M}{k\delta\rho d^2} \text{ or } C = \frac{M}{id^2} \text{ where } i \text{ is a form factor.} \qquad (3)$$

Retardation due to drag (D) then becomes

$$r = \frac{D}{M} = \frac{E(v)}{C} \tag{4}$$

For the purpose of determining the factors controlling retardation, we will substitute the value of D in (2) for D in D/M in (4) which results in

$$r = \frac{k\delta\rho d^2 v^2 f\ (v/a)}{M} \tag{5}$$

In evaluating the effect of each of the several elements affecting retardation, the constants k and δ may be disregarded. d^2/M is simply another expression for the term "sectional density" (A/M where A is the area). Retardation decreases as this fraction approaches zero as a limit. Hence as d^2 decreases, retardation decreases. In other words, the most efficient shape for sustained velocity is the needle or cylinder of maximum mass and minimum area of presentation.

Velocity of the moving projectile affects retardation as v^2. The greater the velocity the greater the rate of retardation. Doubling the velocity multiplies the retardation factor by four.

During the air flight of a projectile, the density, ρ, is considered to be unity under average conditions near the ground. However, when considering retardation in a dense medium such as water or tissue, ρ is a factor of 800 or more.

Mach number, or the function v/a, is important in that it has been determined that the velocity of sound in a medium is a critical velocity. Using 1,100 f.p.s. as the average velocity of sound in air near the ground level, some values of v/a are tabulated:

v(*f.p.s.*)	v/a	v(*f.p.s.*)	v/a
500	0. 45	4, 000	3. 64
1, 000	. 91	5, 000	4. 55
1, 500	1. 36	6, 000	5. 45
2, 000	1. 82	7, 000	6. 36
3, 000	2. 73		

From this tabulation, it is immediately apparent that a missile moving in air at 7,000 f.p.s. is retarded more than six times as quickly as the same missile moving at the rate of 1,000 f.p.s. This is an explanation of the fact that supervelocities and the consequent devastating wounds are only to be encountered quite close to the point of fragment departure. Supervelocity missiles are rapidly retarded to the lower velocities even in air.

Extrapolation of the formulas for the motion of a projectile in air to the motion in much denser mediums such as water and tissues is questionable. Too many little known, or unknown, factors are involved. However, by

collecting the unknown factors in K_D, the drag coefficient (C_D) in a dense medium may be represented by

$$C_D = K_D \rho v^2 d^2 \tag{6}$$

where K_D=summation of unknown factors affecting drag.
ρ=density
v=velocity
d=diameter

The drag coefficient can be determined experimentally when the velocity of a missile can be plotted against the time. Let α= the retardation coefficient and we have

$$\frac{dV}{dt} = \alpha V^2 \tag{7}$$

where V=the instantaneous velocity
and t=the time

For the determination of the drag coefficient we have:

$$\alpha = \frac{\rho A\, C_D}{2M} \tag{8}$$

where ρ=density
A=area
M=mass

High-speed motion pictures of missiles moving in water and gelatin gel have permitted the determination of dV/dt and from this α and in turn C_D (6). The work was done with steel and aluminum spheres ranging in diameter from one-sixteenth to one-fourth of an inch. In water, C_D was found to fall between 0.30 and 0.33 from a summary of coefficient data, and the observed value was 0.314.

While it is presumed logical that $f(v/a)$ is equally applicable to retardation formulas pertaining to the denser mediums, its application is less important because of the usually higher value of a. In water, the velocity of sound is more than 4,500 f.p.s. and much greater than this in many metals and other hard materials. It is presumed that the velocity of sound in most tissues is similar to that in water, considering their average composition and density. In view of this, at most impact velocities, the factor v/a is less than one and comparatively unimportant in affecting retardation. For example, suppose v to equal 900 f.p.s. while a is 4,500 f.p.s. Then v/a equals 900/4,500 or 0.2.

This leaves as significant factors in considering retardation in dense mediums, ρ, and A/M and v^2. Compared to air, ρ is much greater—800 or more. A/M and v^2 retain their same significance.

In considering missile penetration of armor, concrete, and stone, other factors inherent in the material penetrated must be considered. Similar factors do not appear to be pertinent in tissue penetration with the possible exception of bone. However, for our purpose, any special properties of bone can be temporarily, at least, disregarded, as the extent of bone penetration compared to soft-tissue damage is usually insignificant.

Shape

Random shape.—In shell or bomb fragments, pieces of glass, sand, and stones, missiles may have any possible shape. Few have the shapes or are so propelled that A/M or sectional density is a minimal value. Retardation in air is rapid. Table 20 illustrates how rapidly velocity falls with fragments from the burst of a 100-pound general-purpose bomb (the lightest effective fragment is one capable of penetrating ¼-inch mild steel).

TABLE 20.—*Retardation of effective fragments at varying distances from point of burst of a 100-pound general-purpose aerial bomb*

Distance from burst	Weight of fragment	Velocity
Feet	*Ounces*	*F.p.s.*
20	0. 022	7, 320
30	. 029	6, 390
40	. 039	5, 660
60	. 060	4, 760
80	. 086	4, 140
100	. 115	3, 780
120	. 150	3, 470
140	. 191	3, 110

Bullets, artillery projectiles, and rockets are launched point on so that the factor A/M is minimal. Bullets and artillery projectiles are further essentially stabilized in this minimal presentation through a high rate of spin about the long axis imparted by the rifling in the gun barrel. Random missiles seldom have a spin about the axis of flight but are more apt to whirl or tumble through the air. Retardation is more rapid because of the excessive area presented for the air to act upon.

Random fragments frequently have a shape conducive to excessive retardation as compared with the ideal form. Here the function v/a also plays an important role. The ideal shape when a is greater than v is the so-called teardrop section with the round portion to the front. When v exceeds a, the ideal shape is a pointed form, ogival or paraboloidal in section with the point to the front. For minimal retardation, surfaces should be smooth. Random missiles from bombs, artillery, and rocket projectiles are usually rough. Secondary missiles of sand and pebbles may be quite smooth and perhaps approach

the teardrop so far as leading edge presentation is concerned. Secondary missiles of glass may be quite pointed and are often likely to fly point on because of the vane action of their surfaces. In glass fragments, A/M may be favorable, A being minimal for the fragment and M fairly high considering the density of slightly more than 2 for glass as compared to nearly 8 for steel and more than 11 for lead. The density of sand is similar to that of glass.

Fragments consistently have less mass than bullets, size for size, owing to the approximately 50 percent greater density of lead as compared with that of steel, a representative fragment material.

Shell and rocket-projectile fragments are apt to be larger and consequently heavier than those from the usual general-purpose bomb and so have a better sustained velocity. Special antipersonnel aerial bombs may be constructed in such a fashion that fragments will be of a mass sufficient to sustain impact velocities at a level adequate to produce casualties at some distance from the point of burst. Also, through selection of metal and design, there can be some control of fragment shape. An instance of shape control is the corrugated casting used in the Mills hand grenade of World War I.

Ballistic shape.—The term "ballistic shape" as applied to missiles is employed to refer to those missiles specially designed to have the best possible exterior ballistic characteristics. In the missile-casualty field, the small arms bullet is probably the only missile falling properly in this category because of shape and controlled flight through spin imparted by rifling in the gun.

The effect of missile shape on retardation is strikingly shown in table 21 which lists the remaining velocities at different distances from the point of origin for fragments from a 4.5-inch HE shell and the M1 150-grain bullet. Initial velocities are similar, approximately 2,800 f.p.s., in each case.

TABLE 21.—*Retardation of effective fragments from an HE shell as compared with the M1 bullet*

Distance from point of origin	Velocity of—	
	Effective shell fragment	M1 bullet
Feet	*F.p.s.*	*F.p.s.*
0	2, 800	2, 800
50	1, 560	2, 710
100	1, 360	2, 645
150	1, 150	2, 580
200	1, 020	2, 525
300	890	2, 440
400	------------	2, 365
500	------------	2, 300

Three major types of shape are encountered in military small arms missiles: Flat base with rounded nose; flat base with pointed nose; and tapered or so-called boattail base with pointed nose.

The first form is commonly used in sidearms, carbine, or other ammunition where velocities at battle ranges will be less than that of sound in air. The second shape was developed in the first decade of the 20th century to improve the flight of military bullets when muzzle velocities were developed to twice or more the velocity of sound in air. The taper-base bullet was a later development to permit of greater mass and better flight when the moving bullet was retarded to or below the velocity of sound in air. At first, many observers considered the taper-base bullet to be more accurate, but its accuracy was found to be due, in all probability, more to necessary improvements in manufacturing methods than to its shape alone. This bullet is slightly more stable in air flight because of the greater distance from center of gravity to center of pressure.

Careful analysis of bullets manufactured for match competition has demonstrated that care in base design and production is more important to accuracy than similar care regarding precision in the nose shape.

Theoretically, the bullet, or any projectile for that matter, to be accurate should be a perfect form of revolution with the center of gravity in the axis of revolution. While this attainment is approximated, perfection is impossible, especially in a missile assembled of various nonhomogeneous materials. Some asymmetry of mass distribution or shape or both is the rule rather than the exception.

Futhermore, when a bullet passes through the gun bore in launching, there is an asymmetrical engraving by the lands of the rifling. Again in manufacture, bullets are usually pressed into form at pressures of something less than 10 tons to the square inch. In firing, powder gas pressures against the base of the bullet are usually of more than 20 tons to the square inch. This results in deformation.

In the .30 caliber rifle barrel, the bore diameter is 0.300 inch and the groove diameter 0.308 inch. Bullets made of a homogenous material on a lathe and measuring 0.310 inch in diameter have been fired through accuracy barrels with a groove diameter of 0.308 inch and recovered after firing. On recovery, they still measured 0.310 inch in diameter, demonstrating either gun barrel stretch or temporary compression of the bullet or both.

Considerable heat is developed by the friction of the bullet in passing through the gun bore, and the temperature of the powder gases is high (above that of molten steel). There is some evidence that the lead core of bullets under certain conditions can be altered at least during the earlier portion of its flight. This permits some core deformation with consequent asymmetry of mass distribution.

Inherent and induced asymmetry in the bullet results in more or less yaw (deviation of the longitudinal axis from the line of flight) in the bullet during flight. Yaw is an important factor in the physical consideration of the bullet-produced wound and will be discussed later in greater detail (p. 127).

Mass

Table 22 shows the velocities of fragments of varying weight and random shapes at several distances from the point of a bombburst and demonstrates clearly the effect of mass (really the factor A/M) on impact velocities. The initial fragment velocity in all cases was 7,390 feet per second.

TABLE 22.—*Effect of mass on the retardation of fragments*

Distance from burst	Weight of fragment	Velocity	Retardation
Feet	*Ounces*	*F.p.s.*	*F.p.s.*
80	0. 012	2, 230	5, 160
80	. 023	3, 150	4, 240
80	. 085	4, 160	3, 230
80	. 390	5, 180	2, 210
200	. 061	990	6, 400
200	. 148	1, 710	5, 680
200	. 345	2, 510	4, 880
200	1. 05	3, 550	3, 840
500	. 214	531	6, 859
500	1. 08	972	6, 418
500	2. 12	1, 400	5, 990

From this table, it is immediately apparent that at any given distance from the point of launching, initial velocities being comparable, the heavier missile will have the greater impact velocity. This follows from the retardation formula, retardation varying inversely as the mass.

Furthermore, the factor d^2/M or A/M will consistently decrease as M increases, presupposing the fragment to be of the same material. Mass increases as the third power, while the corresponding area increases as the square. Doubling the size of a mass increases the weight eight times and the area four times in homologous shapes.

This principle underlay the development of the taper-base bullet. For instance, the .30 caliber flat-base bullet weighs 150 grains versus 172 grains for the taper-base bullet. Both have essentially the same bearing in the gun rifling, barrel friction is comparable, and gas check is equally efficient. In the German 7.92 mm. bullets, the weights are 154 grains for the flat-base versus 197 grains for the corresponding taper-base bullet. Impact velocities at any given range with these bullets will vary almost as the weight ratio, that is, as 172 : 150 or 197 : 154, if the bullets are launched with the same initial velocity.

Originally, the .30 caliber 172-grain taper-base bullet was loaded in ammunition for a muzzle velocity of 2,700 f.p.s., the same as that of the 150-grain flat-base bullet. For ballistic reasons, muzzle velocities were subsequently reduced to approximately 2,640 f.p.s. Some personnel also complained of recoil as being excessive and impairing marksmanship.

In this connection, it is to be noted that the recoil of a weapon is a function of the relative masses of the gun and bullet and the muzzle velocity of the projectile. Any decreases in weight of gun, increase in weight or muzzle velocity of the bullet will increase the recoil.

The Germans launched their 197-grain taper-base bullet with a muzzle velocity of approximately 200 f.p.s. less than that used with the flat base, 154-grain bullet (2,480 to 2,500 f.p.s.). The Japanese also launched their 196.9-grain 7.7 mm. taper-base bullet at a fairly low velocity, 2,239 feet per second.

Area of Presentation of Random Fragments

Theoretically, the area of presentation of a random fragment may be anything from a minimum (a) to a maximum (A) possible for any given fragment. However, mathematical investigation indicates that the average area of presentation in random fragments will be approximately 70 percent of A.[12]

Explanation for this lies in the fact that, because of the asymmetry of form as well as the unequal application of the impelling forces, fragments commonly have whirling or tumbling motions in addition to the motion of translation. In general, the greater the area of presentation in relation to the mass, the greater will be the retardation and the lower the impact velocity.

Shape can affect area of presentation. A round ball, for instance, has only one possible area. On the other hand, a rectangular object may have many possible areas of presentation from the minimum to the maximum section possible.

Bullets and projectiles are designed to afford the minimum area of presentation combined with the maximum possible mass. Minimum area of presentation is maintained through the action of the spin about its longitudinal axis imparted to a projectile by the rifling in the gun barrel. Rifling of a gun barrel was a major improvement accomplished in the latter part of the 18th century.

Yaw

Yaw, deviation of the longitudinal axis from the line of flight, in a bullet without doubt plays a most important role in explaining many of the anomalies encountered in the study of bullet wounds. Yaw is increased proportionately to the relative densities of the retarding medium as compared to air, so in tissues it is augmented some 800 times, with resulting very complex, rapid bullet motions. This rapid, complex motion accounts for wound damage much more extensive than attributable to motion of translation alone. Yaw augments the retardation of a bullet in tissue, thereby materially increasing the amount of kinetic energy entering into the wound production.

[12] Morse, H. M., Baldwin, R., Kolchin, E.: Report on the Uniform Orientation and Related Hypotheses for Bomb Fragments, With Applications to Retardation and Penetration Problems. Report No. T.D.B.S. 3, Office of Chief of Ordnance, Washington, D.C., 30 Jan. 1943.

Yaw results from two factors: (1) Spin imparted by rifling; (2) imperfections in the bullet due to construction or deformation in the bore of the gun and imperfections in the gun.

To have a yaw, a bullet must have a length greater than its diameter. There can be no yaw in a round ball. In flight, the forces of retardation can be resolved in a point within the moving object. In addition, there is within the solid the center of gravity and in the sphere the two points coincide, hence there is no lever between the two points about which an overturning force can operate.

In the bullet, or cylinder, in flight in a point-on orientation, the point at which the opposing forces are resolved will be different from the center of gravity. An overturning force will operate on the lever between these two points. Without spin, the bullet will tumble end over end.

With the muskets and smoothbore guns of the 17th and 18th centuries, round balls were employed. Bore diameters of guns were larger than in modern weapons, and powder pressures and velocities were comparatively low.

American hunters required accuracy and range. This naturally led to smaller bore weapons and longer barrels which, while decreasing the mass of the ball, resulted in increased velocities and range. As velocities are increased with the round ball in a smoothbore barrel, accuracy is lost. The ball may be quite erratic in flight. The idea of imparting spin to the missile by means of rifling naturally followed. This restored accuracy. It is now known that the inaccuracy of the ball is due to air piling up in front of it and that spinning the ball prevents this accumulation of air. The cylindrical bullet gradually evolved during the 19th century, and rifle calibers declined with powder improvement. The U.S. military weapon for some years was the Springfield .45–70, which fired a heavy lead bullet weighing more than 400 grains. This was followed near the end of the 19th century by the Krag-Jorgesen rifle of .30 caliber and a 220-grain jacketed bullet. In 1903, the Springfield magazine rifle of .30 caliber was adopted. At first, a rounded-nose bullet was used, but this was replaced in 1906 with the so-called spitzer bullet with an ogival head having the ogive struck with a radius of 7 diameters (calibers). This ogival head was developed in Germany early in the 20th century, and the first patent application in the United States was filed in 1905.

Most of this gradual change and improvement in bullets up to the period of World War I was largely accomplished by rule-of-thumb or crude scientific methods as judged by modern standards.

In the period of a little more than a century and a quarter following 1775, the following changes in military weapons slowly evolved:

1. The rifled bore, putting spin on the bullet.
2. Gradual transition of the bullet from the round to the elongated shape.
3. Gradual change from a round nose to the sharp pointed, ogival, so-called spitzer nose.

During this transition, the pitch of the rifling was gradually changed until most military weapons used a twist of approximately one turn in a distance

of 30 calibers.[13] While it is customary to state that the rifling makes a turn in so many inches, it is better to specify the pitch in calibers, which immediately permits of comparisons between weapons of differing calibers.

Pitch of rifling through determining the rate of spin is a factor in controlling the stability of the bullet in flight and in turn the degree of yaw on impact. The rate of spin in the usual military rifle is high. With the .30 caliber flat-base bullet at a muzzle velocity of 2,700 f.p.s. and a rifling pitch of 30 calibers, the spin is more than 3,500 revolutions a second. This spin is only adequate to stabilize the 150-grain bullet in air flight. The spin has a negligible effect in maintaining the bullet in a point-on position in denser mediums, such as water or tissues.

Spin maintains the bullet essentially in a point-on position through its effect on what is known as the overturning couple. In the elongated bullet, all retarding forces are resolved in a point somewhere in the axis of the bullet toward the nose. The center of gravity also will be in the axis but at a point nearer the base in the pointed-nose bullet. The distance between these points is the overturning couple, or lever arm, through which the forces resulting from the spin operate to stabilize the bullet.

Because a bullet is never a perfect form of revolution and because neither the center of pressure nor center of gravity is exactly in the axis, there is always some degree of yaw or tip or gyroscopic precession. Owing to the gyroscopic action of the high rate of spin, this yaw goes through a definite period which varies throughout the bullet's flight. Another factor inducing initial yaw is that, while the bullet passes through the gun barrel, the center of gravity is forced to travel in a circle so it will not be in the axis of the bore, whereas, once the bullet is in free air flight, the rotation is about the center of gravity, which immediately takes over.

Length of bullet determines the relative location of the centers of pressure and gravity and through that the length of the lever arm through which the forces of spin operate. This makes the longer, taper-base bullet somewhat more stable than the usual flat-base form.

However, density of resistant materials is a direct factor on the retardation and other motions of a missile. Water with a density 800 times that of air and tissues of slightly greater densities act much as a magnifying glass, magnifying all of the retardations, yaw, and gyrations of the bullet 800 or more times. A very slight tip or yaw will become one of more than 50° by the time a .30 caliber 110-grain solid bullet homologous in shape with 150-grain flat-base bullet has traversed 3 inches of water. Not infrequently, the increase in yaw will exceed 100°. Changing from one density to another also induces marked variations in the degree of yaw.

This, of course, immediately changes the area of presentation; a bullet enters tissue point on but in a few inches may be tipped up to 90° or more and the

[13] The caliber of a weapon is the diameter of the bore not including the depth of the grooves. A unit of caliber is also used to express the length of an artillery weapon from breech face to muzzle and is equal to the diameter of the bore. For instance, many naval guns have a length of 50 calibers.—J.C.B.

presentation area is its broadside. The forces of spin are still operating, however, through the overturning couple and tend to stabilize and maintain the bullet in point-on flight. Consequently, in another few inches, the bullet is again point on and may leave the body through a small exit wound. Neither entrance nor exit wounds give any idea regarding the extensive interior destruction occasioned by the extreme tip and periodic bullet gyrations within the tissues.

While in flight, the bullet goes through all of the motions of the spinning top, except that it is much quicker because of its higher rate of spin. Some conception of the rate of spin may be visualized when it is realized that it is more than 100 times that of what is usually termed a high-speed electric motor armature which is rotating more than 1,700 revolutions per minute. The MII bullet with a muzzle velocity of 2,800 f.p.s. spins at a rate of more than 200,000 revolutions per minute. The usual top spins at a few hundred turns a minute but is relatively better balanced than the bullet.

When a top is started spinning, it wobbles more or less in a periodic manner. Then it stabilizes and, if well made, spins quite stably for an appreciable interval. Then, as it loses spin, it again becomes unstable and wobbles more and more as the spinning motion retards. The spinning bullet goes through similar gyrations while moving through the air. However, while the top goes through its gyrations with its point as a fulcrum, the fulcrum about which the bullet's axis tips is the center of gravity of the bullet.

These varied motions are gyroscopic in nature and strictly periodic. At one instant, the bullet is point on, and at the next instant the bullet axis is at an angle to the line of flight. This angle of yaw increases to a certain amount and then progressively decreases until it is again zero, when a node is reached and another similar gyration commences.

In air flight, degree of yaw is normally comparatively slight—less than 3° in properly designed military bullets. This spin is sufficient to stabilize the bullet in an essentially point-on position. The bullet goes through a complete gyration in a distance of 10 to 20 feet, at less than 0.001 second of time.

As the bullet leaves the muzzle of the gun, the actual angle of yaw is very small, only a few minutes of arc, but the angular velocity of yaw is considerable so that as the bullet moves along its trajectory the yaw increases until it reaches a maximum at some 10 or 15 feet in front of the muzzle. From here, it then proceeds to yaw in an approximately periodic manner throughout the remainder of its flight.

The angular velocity of the yaw is usually due to one of the following causes or a combination of them. It may be due to the fact that the axis of the bullet makes an angle with the bore so that the axis of the bullet is moving in a cone around the axis of the bore. This conical motion provides for the angular velocity just mentioned. Another cause is due to some asymmetry or inhomogeneity in the bullet which may result in the major axis of the ellipsoid of inertia of the bullet having a different direction from the axis of form. The result of this sort of angle is equivalent to the result produced when the axis of

the bullet makes an angle with the axis of the bore. The gyroscopic forces of spin quickly damp out the initial yaw so that at a distance of a hundred yards or so the bullet is flying almost exactly nose on.[14]

Bullet spin is retarded less rapidly than the motion of translation. However, at long ranges, several thousand yards or more, the bullet presentation is further complicated by the fact that the gyroscopic forces of spin tend to maintain the bullet's axis parallel to the axis of the gun throughout its flight. The axis of the bullet does not tend to follow the trajectory except for a short distance from the gun. As an example, if a bullet is fired from a gun elevated at an angle of 30°, the axis of the bullet tends to maintain this 30° angle throughout its flight. This results in asymmetry of the retarding air forces with respect to the bullet axis and consequent increase in angle of yaw at extreme ranges as the axis of the trajectory deviates from the direction of the axis of the gun bore.

Surgeons have often noted "key-hole" entrance wounds at extreme ranges and erroneously attributed them to "tumbling" bullets. In unimpeded air flight, a bullet given adequate initial spin seldom "tumbles" or flies end over end. Of course, a bullet often tumbles badly after striking a glancing blow in ricochet. However, at extreme ranges, a bullet seldom flies with its axis parallel to the ground, so often hits with its axis far from perpendicular to the surface struck. The entrance wound is usually an accurate record of the bullet's presentation at the instant of impact.

On entering a medium denser than air, all of these motions, especially the degree of yaw, are magnified. On entrance, yaw may be only a fraction of a degree, but it is quickly increased by approximately the ratio of the medium densities which for water and tissues is some 800 times. Likewise, period of gyration or distance from node to node is correspondingly shortened. A bullet may be essentially point on at impact and in a space of 3 inches be tipped in yaw at right angles to its line of flight and in another 3 inches again be essentially point on.

Moving from a medium of one density to that of another density influences the bullet's motions and can result in extreme angles of yaw. For instance, moving from air to tissue, from soft tissue to bone, and again from bone to soft tissue will have a profound influence in inducing extreme changes in the gyrations of the bullet and all of its motions, including retardation.

Retardation for any bullet also varies as the square of the angle of yaw in degrees so that a yaw of 13° will double the retardation.[15] Letting δ be the angle of yaw in degress, the retardation factor due to yaw is

$$1+\frac{\delta^2}{169}$$

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[14] Personal communication, R. H. Kent, Physicist, Aberdeen Proving Ground, Md., to Maj. R. W. French, 28 Mar. 1947.

[15] Kent, R. H.: The Theory of the Motion of a Bullet About Its Center of Gravity in Dense Media, With Applications to Bullet Design. [An undated manuscript sent to Major French in the period 1931–32.]

Table 23 gives the retardation factor for varying values of yaw.

TABLE 23.—*Values of yaw*

Yaw	Yaw^2	$Yaw^2/169$	$1+Yaw^2/169$
Degree	*Degree*		
2	4	0. 0236	1. 02
4	16	. 0944	1. 09
8	64	. 3776	1. 38
16	256	1. 5104	2. 51
32	1, 024	6. 0416	7. 04
64	4, 096	24. 1664	25. 17
128	16, 384	96. 6656	97. 67

Yaws of more than 170° have been observed in bullets in passing through 6 inches of water. Theoretically, yaw can be of any value to just under 180 degrees. A yaw of 170° increases the retardation factors 172 times and a yaw of 179°, 190 times. This readily explains why a superspeed bullet is stopped in a very few feet of a homogeneous medium such as water.

This also explains why a supervelocity bullet is retarded so greatly in producing a casualty. The extreme retardation of such bullets can result in a wound with comparatively enormous destruction, tissue pulping, bone shattering, and other extreme manifestations only possible with the modern, fast-moving military bullet.

THE WOUND AS A PHYSICAL ENTITY

Permanent manifestation of the missile wound is a hemorrhagic area surrounding the track of cut and torn tissue left in the missile wake. However, while cutting through the tissue, a missile also imparts radial velocity to the tissue elements resulting in a development of a temporary cavity as the tissues absorb the kinetic energy lost by the missile through retardation. In absorbing this energy, some tissues more elastic than others react in such a manner that this cavity goes through several pulsations, each successive temporary cavity being smaller in volume than the preceding cavity. In longitudinal section, the temporary cavity is a conic section, usually an oblate ellipsoid in the case of a missile without yaw or particular form factor, such as a sphere.

In producing a casualty, the missile is commonly moving in the tissue a thousandth of a second or less, and the actual wound is produced too rapidly for human perception to appreciate all that goes on. As examples of actual time intervals involved, the following two instances are cited, considering the thigh with a thickness of 8 inches to be the part injured:

First, consider a bullet weighing 150 grains with an impact velocity of 2,500 f.p.s. and a residual exit velocity of 1,500 f.p.s. It will traverse the 8 inches of tissue and bone in 0.00033 second and expend 1,330 ft.-lb. of energy during its passage through the thigh.

Second, the same bullet with an impact velocity of 2,000 f.p.s. and an exit velocity of 1,000 f.p.s. will traverse the thigh in 0.00045 second, and 998 ft.-lb. of kinetic energy will be absorbed in the wound.

On dissection by the military surgeon, the most prominent feature of the wound will be the permanent cavity or wound track which on close inspection is found to be surrounded by a zone of more or less damaged tissues filled with extravasated blood. Partially or completely disrupted nerves may be found along with damaged blood vessels, though, barring a direct hit by the missile, most of the larger veins will be intact and the arteries uninjured. Bone may be found to be fractured without evidence of a direct hit. Such fractures are usually fairly simple, while those which result from a direct hit will show more comminution, especially at the cited impact velocities.

Research with spheres [16] as missiles has demonstrated that both the volume of the permanent cavity and the tissue showing evidence of devitalization and extravasation of blood is a function of the kinetic energy entering into the wound; also, that the volume of the tissue showing extravasation is 11.8 times the volume of the permanent cavity. It is anticipated that with bullets the degree of yaw will modify the direct relationship between volume and impact energy or square of velocity.

Further research with steel spheres has demonstrated that, some 400 microseconds after impact, a temporary cavity some 26 times the volume of the permanent cavity reaches its greatest diameter perpendicular to the path of the missile. This cavity may go through several pulsations with corresponding negative and positive pressure phases. All of these phenomena are too rapid to be perceived by the human eye.

This temporary cavity and associated phenomena explain the so-called explosive effects often noted with high-velocity missiles. It accounts for tissue pulping and other damage some distance outside of the permanent cavity or apparent bullet track. During the stretching of tissue concurrent with the expansion of the temporary cavity, nerve trunks are often stretched to such a degree that function is destroyed without apparent gross injury.

Permanent Cavity

As the missile tears through the tissues, there are two immediate results: (1) The cutting or tearing of a permanent cavity along its track; and (2) the initiation of severe shock waves, with pressures of well over 1,000 pounds to the square inch, which travel ahead of and out from the missile at the velocity of sound in the tissues, approximately 4,800 feet per second.

[16] For the complete report of this work, see pages 147-233.

Experiment has demonstrated that for every foot pound of energy doing work in wound formation there will be a permanent cavity remaining with a volume of 2.547×10^{-3} cubic inches. With the average military rifle bullet and resultant wound, this presages a permanent cavity slightly larger in average diameter than the bullet. Yaw may modify the shape of the permanent cavity from point to point along the track, but the total volume should follow this expression as yaw also modifies the amount of energy doing work.

In the case of slow low-energy missiles, the permanent cavity will be distinctly smaller in diameter than the missile which produced it. Tissue elasticity accounts for the reduction in volume.

While the passage of the missile is responsible for the permanent cavity, it actually comes into permanent being sometime after the missile's passage. As the bullet passes through the tissue, considerable radial motion is imparted to the tissue elements, and a large temporary cavity is formed. Slow-motion pictures and other experimental evidence show that there are several pulsations before the wound track becomes wholly quiescent. This again is probably due to tissue elasticity, particularly the restraining action of the skin as it absorbs the energy imparted to it by the missile.

Area of Extravasation

On dissection of the wound track, the adjacent tissue is found to be quite sanguineous and, in the case of the average rifle-bullet wound, full of extravasated blood for an inch or more away from the track. In this region, histologic examination reveals a separation of muscle bundles with capillary hemorrhages into the interspaces.

In cross section of a wound track, this hemorrhagic area is found to be well defined. Experiment has shown that for every foot pound doing work in producing the wound there will be 30.105×10^{-3} cubic inches of this hemorrhagic tissue.

Survival studies have suggested that much of the tissue in this area of extravasation will regenerate if it is kept clean. However, in the battlefield, cleanliness is often impossible, and this pulped, hemorrhagic tissue provides an excellent pabulum for pyogenic bacteria and the clostridia which are responsible for gas gangrene. Early, adequate debridement is the indicated procedure in order to guard against secondary invaders and to insure early healing.

Temporary Cavity

Microsecond X-ray and high-speed motion picture studies have demonstrated the formation of a temporary cavity with a volume almost 27 times larger than that of the permanent cavity. This cavity reaches its greatest size after the impact of the missile and after it has entirely left the wound track. Its maximum volume is 66.247×10^{-3} cubic inches for each foot pound doing work in producing the wound.

In the first hypothetical thigh wound (p. 133) in which 1,330 ft.-lb. of energy were expended, the temporary cavity would have a maximum diameter of perhaps 12 or 15 inches, depending on the presentation of the bullet. Its total volume would be 88.1 cubic inches.

This temporary cavity, long suspected but never before perceived in tissue, is the logical sequence to the passage of a missile through an elastic medium. Tissues are known to be quite elastic. The pulsation likewise is to be expected in some tissues, such as muscle, as would occur when a ball suspended by a rubber band is dropped. However, the pulsations damp out rapidly, and the human senses are only able to perceive that there has been some general disturbance of the tissues.

Shape of the temporary cavity is a function of the shape and presentation of the missile. With a sphere, the shape of the cavity is quite symmetrical—a conic section of revolution, fusiform in longitudinal section. In the case of a fragment, it may be quite asymmetrical as the presentation of the irregular fragment varies. In the case of the bullet, yaw will result in asymmetry. In fact, where the bullet goes through a node and then again into yaw, there may be several larger temporary fusiform cavities connected by much smaller ones, the so-called scalloped wound remaining in the permanent cavity. Variations in tissue also affect the type and shape of cavity.

This cavity is the result of particles set into motion by the passage of the bullet. Time is required to overcome their inertia, hence the lag in full development of the temporary cavity as compared to the passage of the bullet. While the missile imparts outward moving forces to the particles at the instant of its passage, it requires some microseconds for the particles to move outward to their greatest distance and for the physical properties of the tissues to absorb the forces involved. Average particle velocities are not particularly great. In the hypothetical thigh shot, they would be 125 feet per second.

While foot pounds, units of energy, have been used in discussing the mechanics of the missile wound, a better conception of the magnitude of the forces involved may come from a consideration of the power utilized in wound formation. Power is the measure of work done by the energy expended by the missile in the wound. The 1,330 ft.-lb. absorbed in 0.00033 second in the first hypothetical wound is the equivalent of some 7,200 horsepower of work. In the second wound (p. 133) with 998 ft.-lb. absorbed in 0.00045 second, the work equivalent is more than 4,100 horsepower. Work done in any missile wound will seldom be less than several hundred horsepower and will often considerably exceed the figures cited. The larger numerical values of horsepower can be expected when it is realized that 1 horsepower is the lifting of 550 pounds for 1 foot in 1 second. In the wound, more than 1,000 ft.-lb. of energy may do its work in much less than one-half of a thousandth of a second.

With this realization of the forces involved in the production of the missile casualty, some of the otherwise anomalous manifestations in the wound appear much more logical. For instance, fractures occur at some distance from the

missile track and without any direct contact between the bone and the missile. Forces may be transmitted through the essentially noncompressible blood and rupture a vein some distance from the missile's path. Nerves may be paralyzed and yet fail to show gross evidence of physical damage. In some wounds in muscle, splitting along fascial planes will be noted for a considerable distance from the path of the bullet.

Fluid-filled viscera are often blown asunder by the operation of hydraulic forces. High-velocity missiles may pulp the brain substance. In some cases, the bones of the skull are separated along the suture lines as though an explosion has occurred within the brain case. This is but another manifestation of the forces operating in the formation of the temporary cavity, and examination often reveals clean holes of entrance and exit of the missile showing that the bony rupture occurred after its passage. Similarly, in shooting through a can filled with water, the rupture of the can occurs after the through-and-through passage of the bullet.

Knowing the relationship between the permanent cavity, zone of extravasation, and temporary cavity, the military surgeon can make use of this knowledge in determining the extent of the wound. The zone of extravasation is readily seen and can indicate the total involvement. For instance, if an area of tissue full of extravasated blood is seen extending for a distance of 2 inches from the axis of the permanent cavity, it is known that damage along fascial planes, perhaps some blood vessel rupture, and some nerve injury can be expected to a further distance of some 2½ inches beyond the zone of extravasation. If note is made of the extent of extravasation, some idea as to the amount of energy expended in the wound is determinate.

The military surgeon should never be misled, especially in the case of bullets, by small entrance and exit wounds. These small skin openings may be no indication whatever of the possible extent of the internal wound. This is particularly true of the yawing bullet and may be true of the high-velocity, spinning fragment. Elasticity of the skin often results in almost complete closure of skin wounds.

Temporary Cavity Pulsations

In water and certain tissues, such as the muscular thigh surrounded by highly elastic skin, the temporary cavity goes through a series of pulsations. As the cavity expands, a negative, subatmospheric gage pressure develops within the tissues. This is followed by a positive pressure of greater intensity but of shorter duration with the collapse of the cavity. In water, these pulsations may continue for as many as seven or eight cycles, disappearing as the cavity disintegrates. While measurements of tissue phenomena have not been made as complete as those in water, definite indications are that the tissue often behaves in a manner wholly analogous to water. There may be two or more pulsations.

For water, the period of the pulsations is related to the amount of energy doing work. The time of a cycle in seconds is equal to 2.35×10^{-3} times the cube root of the foot pounds of energy absorbed. This relationship also is reasonably applicable to most tissue wounds. The following tabulation gives the computed time of a complete pulsation in milliseconds for varying amounts of energy in foot pounds:

Energy (*ft.-lb.*):	*Duration of pulsation (milliseconds)*
250	15
500	19
1, 000	23
1, 500	27
2, 000	30

Coupled with the temporary cavity in water and its pulsations there are internal pressure changes. When the cavity is fully expanded, pressures in the medium are at their lowest value, often a full atmosphere or more subnormal. As the temporary cavity decreases in size, pressures increase reaching a maximum value of three or four times atmospheric pressure. Oscillograms reveal that, while the positive pressures are greater in intensity, the duration of the negative pressure phase is twice as long.

While the initial shock wave shows very high pressures (1,000 pounds per square inch and more), oscillograms show its duration to be short, 15 to 25 microseconds. Available evidence indicates that this short duration may explain the apparent fact that little if any true tissue damage in gas-free tissues can be attributed to this initial shock wave despite its intensity. Other studies have shown that tissue elements withstand much higher static pressures without damage.[17] However, when gas is present in the tissue, damage often occurs.

Experimental studies afford quite conclusive evidence that subatmospheric pressures connected with cavity behavior are responsible for much tissue destruction.

Though cavity pulsation has been detected in water, in gelatin block and in some tissues, in abdominal shots in the cat, no pulsations were noted in microsecond X-rays. Here, a single temporary cavity followed by rapid collapse appears to be the rule. However, extensive damage to the intestines occurred which was due largely to the expansion of gas in the intestines in the subatmospheric pressures during the expansion of the temporary cavity and following the shock wave. This expansion of gas results in great stretching of tissues and consequent rupture or other severe damage. This stretching is not due directly to either the shock wave or cavity formation behind the missile but rather to the expansion of the air pocket already present within the tissues. This air responds to the pressure changes around the temporary cavity, and the stretching occurs as the result of the subatmospheric pressures when the included air expands.

[17] (1) Brown, D.E.S.: Effects of Rapid Compression Upon Events in Isometric Contraction of Skeletal Muscle. J. Cell. & Comp. Physiol. 8: 141-157, 1936. (2) Cattell, M.: The Physiological Effects of Pressure. Biological Rev. of Cambridge 11: 441-476, 1936.

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Though not established experimentally, it is anticipated that the subatmospheric pressures may likewise lead to sudden expansion of gas in the alveoli in the lungs so as to stretch the walls and rupture small blood vessels. Such injury is indicated from field observations.

The extent of the temporary cavity formation and the relationship of tissue damage to the permanent wound track may be influenced by constricting clothing, tenseness of muscles, or other variables at the time of wounding. For instance, removing the skin from a cat's leg before wounding resulted in a larger temporary cavity with more of a wound "blow-out." On the other hand, reinforcing the skin with Scotch tape changed the shape of the cavity and resulted in tissue damage to a greater distance from the missile track. Elasticity of the skin and muscle fibers appeared to play a considerable part in predetermining the physical nature of the missile wound.

Skin Penetration and Energy Absorption [18]

Skin and bone both appeared from experimental data to offer a particular resistance to penetration differing from other tissues. There was a critical velocity in each case below which a missile would not effect penetration. There was comparatively little difference in the value of this critical velocity irrespective of the size of the missile.

Initial velocity required for a 4/32-inch steel sphere weighing 2 grains was found to be 170 f.p.s. for penetration of human skin. Lead spheres having an 11/64-inch diameter, weighing approximately 7 grains with a velocity of 161 f.p.s., did not effect penetration. Even extremely large missiles will lose about 125 f.p.s. of their impact velocity in penetrating the surface of the skin. Area of presentation affects skin penetration to such degree that the loss in velocity is proportional to the reciprocal of the diameter of the spheres.

Skin was found to be more resistant than other tissues. The drag coefficient, a value dependent on the resistance encountered by a missile and independent of the missile, for human skin was 0.528 as compared to 0.297 for water. The coefficient for cat muscle was 0.448 and for 20 percent gelatin block, 0.350. Human skin had a drag coefficient more than 20 percent greater than cat muscle. While the drag coefficient was not determined, indications were that cat skin was slightly more resistant to penetration than human skin.

The skin resistance offered a logical explanation for the fact that shrapnel, formerly used as an antipersonnel agent, was commonly ineffective. It was usually employed at such ranges that remaining projectile velocity was low. The bursting charge propelling the shrapnel balls was commonly incapable of imparting sufficient velocity to effect skin penetration. Shrapnel balls also had a poor ballistic shape and were rapidly retarded in air flight.

[18] Grundfest, H., Korr, I. M., McMillen, J. H., and Butler, E. G.: Ballistics of the Penetration of Human Skin by Small Spheres. National Research Council, Division of Medical Sciences, Office of Research and Development, Missile Casualties Report No. 11, 6 July 1945.

An anomaly in skin penetration was the threshold velocity necessary to effect penetration, rather than a certain amount of energy. A 2-grain sphere required a velocity of 170 f.p.s. for penetration or a negligible amount of energy when measured in foot pounds. For a 150-grain bullet to penetrate skin, a velocity of approximately 125–150 f.p.s. was required corresponding to approximately 5 ft.-lb. of energy. The 2-grain sphere would have less than one-fiftieth this amount of energy.

Bone Penetration [19]

Bone offered a situation similar to that found in skin. Here a minimal velocity of approximately 200 f.p.s. was necessary to effect penetration. Once penetration had been effected, any velocity remaining above the 200 f.p.s. would operate to effect deeper penetration in direct proportion to the square of the velocity and the sectional density of the missile. Penetration and damage to bone was effectively gaged by the amount of energy performing work, essentially proportional to the square of the velocity.

While specific experiments were conducted with beef bone, results are substantiated by other work with human and horse cadavers. Results were essentially the same.

In conjunction with these critical velocities necessary to effect penetration, some consideration should be given to the .45 caliber automatic pistol and its load. From time to time, complaint has been registered that this weapon is not as efficient under all conditions as could be desired in a self-defense weapon. A 234-grain full metal patch bullet is used, and it is launched with a muzzle velocity of 825 feet per second. Following is a tabulation of the kinetic energy available with this bullet at various velocities:

Velocity *(f.p.s.)*:	*Kinetic energy (ft.-lb.)*
825	383
700	254
600	187
500	130
400	83
300	47

Considering the 125 f.p.s. required to effect skin penetration, it can be seen that the remaining velocity and energy are dropped down to at least 700 f.p.s. and 254 ft.-lb., respectively. The penetration of bone requires another 200 f.p.s. and dropping remaining velocity to 500 f.p.s. and energy to 130 ft.-lb. In addition to these losses, passage through tissue results in some retardation, so remaining velocity and energy will certainly be something less than the figures cited. Furthermore, impact seldom occurs at pointblank ranges, and

[19] Grundfest, H.: Penetration of Steel Spheres Into Bone. National Research Council, Division of Medical Sciences Office of Research and Development. Missiles Casualty Report No. 10, 20 July 1945.

the initial velocity is certain to be something less than 825 f.p.s. when the bullet hits the skin.

From an analysis of these facts and the requirements for penetration of skin and bone, it can be readily appreciated that the .45 caliber bullet is of little value as a wound-producing agent except in the softer tissues and at near ranges. The bullet often fails either to penetrate or to fracture bone and practically never shatters bone in the manner common to the rifle bullet or fragment. The Japanese and German sidearms with muzzle velocities of approximately 1,100 f.p.s. were much more effective as antipersonnel weapons than the .45 caliber weapon. While the same bullet with its characteristics was used in the submachinegun, multiple hits probably compensated for the weaknesses, so apparent in single shots.

Of course, the carbine with its much higher muzzle velocity has largely replaced the .45 automatic pistol and is a more effective antipersonnel weapon than any of the sidearms.

Histologic Character of Tissue Damage

Muscle damage is evidenced by swelling and coagulation in a region a few millimeters from the permanent cavity of the wound. Often, no muscle damage is noted in regions where blood extravasation from ruptured capillaries is pronounced.

Expansion of the temporary cavity along fascial planes results in an accumulation of blood from the rupture of small blood vessels, but the larger vessels are remarkably resistant to injury, probably because of their elasticity. Sometimes, a blood vessel is left spanning a permanent cavity. In other cases, nerves are severed, while blood vessels running parallel with the nerve in the same fascia are intact. Veins with their comparatively thin walls often rupture as the result of transmitted forces, while arteries with their more resistant walls are usually patent barring a direct hit.

Cavity Formation by the Moving Missile

As a function of the amount of kinetic energy doing work, the speeding missile results in a permanent cavity, a zone of tissue full of extravasated blood, and a temporary cavity in tissue. In water, it also produces a cavity. The volumes of the various cavities in cubic inches are related to the foot pounds of energy expended by the following formulas:

In tissue:

Permanent cavity—2.547×10^{-3} ft.-lb.

Zone of extravasation—30.105×10^{-3} ft.-lb.

Temporary cavity—66.247×10^{-3} ft.-lb.

In water:

Temporary cavity—737.7×10^{-3} ft.-lb.

Table 24 shows the comparative volumes of the various cavities in cubic inches for varying amounts of energy expended.

TABLE 24.—*Volumes of cavities*

Energy	Cavity in tissue (in cubic inches)			Cavity in water (cubic inches)
	Permanent	Zone of extravasation	Temporary	
F.p.s.				
250	0. 63	7. 53	16. 57	184
500	1. 27	15. 05	33. 13	369
1, 000	2. 55	30. 11	66. 25	738
1, 500	3. 82	45. 16	99. 37	1, 107
2, 000	5. 09	60. 21	132. 49	1, 476
2, 500	6. 36	75. 26	165. 61	1, 845
3, 000	7. 63	90. 31	198. 73	2, 214
3, 500	8. 91	105. 37	231. 86	2, 583

CHAPTER III

Mechanism of Wounding[1]

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HISTORICAL NOTE

Pictures of rifle bullets in rapid flight have always aroused interest and admiration—interest from the resemblance to moving ships with prominent bow and stern waves and a turbulent wake; admiration that so rapid a movement can be stopped in a photograph and the detail of events clearly visualized. Since the first spark pictures of moving bullets in air, obtained by Mach[2] in 1887 and Boys[3] in 1893, a mass of information has been gathered on trajectories, stability, spin, yaw, and precession of projectiles. This field of inquiry is usually classified as exterior ballistics to distinguish it from what happens within the gun, or interior ballistics.

The events which occur when a bullet strikes and enters the body have received much less attention—in part, owing to the rapidity of changes which take place in an opaque medium and the difficulty of measuring them and, in part, to the complexity of the body and the feeling that few significant generalizations could be made regarding it. Actually, the changes which occur when a high-velocity bullet enters soft tissue are remarkably independent of body structure, and a common series of events can be outlined. The recent technical development of high-speed cameras that can take moving pictures at the rate of 8,000 frames a second and an X-ray apparatus that requires only one-millionth of a second for exposure have eliminated the previous barriers to understanding the mechanism of wounding. It is now possible to analyze events that are all over in a few thousandths of a second.

[1] The research on which this chapter is based was carried out under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Princeton University. Work under this contract began on 15 October 1943 and continued to 1 November 1945. On the latter date, the contract was transferred to the Office of the Surgeon General. The work was brought to completion on 28 February 1946. All of the research was conducted in the Biological Laboratories of Princeton University, Princeton, N. J. It is important to record here that the success of the work has been due in great measure to the wholehearted cooperation of the professionally and technically trained persons who, at one time or another, were members of the "Wound Ballistics Research Group." In addition to the authors of this chapter, the following persons took part in the investigation: Mr. Delafield DuBois, Mr. Joseph C. Gonzalez, Mr. Vincent Gregg, Dr. Harry Grundfest, Mr. James J. Hay, Dr. William Kleinberg, Dr. Irvin M. Korr, Mr. Daniel B. Leyerle, Dr. William D. McElroy, Mr. John R. Mycock, Dr. Gerald Oster, Mr. R. G. Stoner, Miss Mary Jane Thompson, Mr. Harold A. Towne, and Dr. Arthur H. Whiteley.

[2] Mach, von E., and Salcher, P.: Photographische Fixirung der durch Projectile in der Luft eingeleiteten Vorgänge. Der Kais. Acad. der Wiss. zu Wein, 1887 and 1889. (Also *in* Nature, London 42: 250–251, 1890.)

[3] Boys, C. V.: On Electric Spark Photographs; or Photography of Flying Bullets, etc., by the Lights of the Electric Spark. Nature, London 47: 415–421, 440–446, 1893.

Thus, a new field of inquiry has arisen, that of wound ballistics, a study of the mechanics of wounding and related subjects. The field has two aspects. One is a determination of the factors involved in injury and the relation between the severity of the wound and such characteristics of the missile as its mass, velocity, shape, momentum, energy, and power. The attempt is made to relate the ability to wound or to kill with some physical property of the projectile. Such inquiry gives an answer to the question, whether an antipersonnel bomb is more effective if it breaks into a large number of small fragments or a smaller number of relatively large fragments.

The second aspect of wound ballistics involves a study of the nature of the damage to tissues, whether it results from stretching and displacement or from pressure changes accompanying the shot. Of particular interest is the commonly observed injury of organs far away from the bullet path. Such knowledge greatly aids the surgeon in his treatment of the wound and is necessary for the establishment of rules for removal of dead tissue and the amount of debridement necessary for proper recovery. The knowledge of wound ballistics is, therefore, important not only in offense but also in defense.

With the perfection of guns that could shoot high-velocity missiles came the observation that the resulting wounds appeared as though they had been caused by an actual explosion within the body. External signs of injury were often slight, the entrance and exit holes small, but an unbelievable amount of damage occurred within. Hugier (cited by Horsley [4]) noted this explosive effect as early as 1848 in Paris, and it has been emphasized by all subsequent writers. Such action has led to mutual accusation by both sides in warfare that the enemy was using explosive bullets. Not only is the tissue pulped within a large region about the bullet path but intact nerves lose their ability to conduct impulses and bones are found to be broken that have not suffered a direct hit.

It is in this explosive effect that high-velocity missiles differ from those of low velocity. The wounds from a spear or a nearly spent revolver bullet correspond more closely to the expected cylinder of disintegrated tissue, little larger than the spear itself. This type of wound can be compared to what happens when a rod is plunged into soft snow. Snow piles up in front and is pushed ahead and to the side, and when the rod is withdrawn a hole is left whose diameter is little more than that of the rod. The situation is far different with high-velocity missiles. They leave behind a large temporary cavity whose behavior is quite comparable to the gas bubble of an underwater explosion. Later, the cavity collapses, but far-reaching destructive effects have occurred during the expansion. A detailed description of what happens during the cavity formation will be found in this chapter.

Much of the early work on wounding was concerned with an explanation of the explosive effect of high-velocity projectiles. Shots were made into various materials, such as gelatin gel or dough, which served as models to

[4] Horsley, V.: The Destructive Effect of Small Projectiles. Nature, London 50: 104–108, 1894.

explain what must happen in the body. Kocher (1874–76) at Berne, Switzerland, was a pioneer in this study, which he rightly thought was a hydrodynamic problem. Delorme and Chevasse [5] in Paris, Bruns [6] (1892) in Germany, and Horsley in England continued the work.

In 1898, Stevenson [7] brought out his monograph "Wounds in War," to be followed by La Garde's [8] "Gunshot Injuries" and by Wilson's [9] account of casualties during World War I. The monumental "Lehrbuch von Ballistik" by Cranz and Becker,[10] now in its fifth edition, first appeared in 1910. In addition to a valuable description of the small arms in use by various nations at the time of publication, these books consider the theories which have been advanced to explain the explosive effect of bullets.

One of the earliest views was that the "wind" of the bullet (that is, its shock wave), or the air compressed on the face of the bullet, was responsible for the explosion. It is quite certain that this view is incorrect since the explosive effects appear if a mass of flesh is shot in a vacuum. Neither can the explosive effect be connected with the shock wave which appears when tissue is hit, since this wave moves through the tissue at the rate of 4,800 f.p.s. (feet per second) and has passed well beyond the wound region before the explosive expansion occurs.

It is a simple matter also to eliminate such theories as invoke rotation of the bullet, flattening of the bullet, or heating of tissues by the bullet as the cause of the explosion. Steel spheres shot from a smoothbore rifle which do not rotate and do not flatten on impact are known to cause explosive effects. Moreover, the kinetic energy of these spheres is not sufficient, even if all were converted into the energy of steam, to account for the explosion.

There remains, as the correct explanation of the explosive cavity, what early workers called the accelerated particle theory. This view regards the energy of the bullet as being transferred to the soft tissue in front and to each side, thus imparting momentum to these tissue particles, so that they rapidly move away from the bullet path, thus acting like "secondary missiles." Once set in motion, the "inertia of the fluid particles" continues its motion, and a large space or cavity is left behind. As Stevenson puts it, the bullet causes damage not only by crushing and attrition of tissue directly but also indirectly by the fluids moving away from its path. Wilson [11] compares this "blasting out" of soft tissues to the effect of the stream of water from a firehose.

Later work has been largely concerned with special aspects of wound

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[5] Delorme, E., and Chevasse, Prof.: Étude Comparative des Éffets Produits Par les Balles du Fusil Gras de 11 mm et du Fusil Lebel de 8 mm. Arch. d. Med. et Pharm. Mil. 17: 81–112, 1892.

[6] Bruns, Paul: Ueber die Kriegschirurgische Bedeutung der Neuen Feuerwaffen. Berlin: August Hirschwald, 1892.

[7] Stevenson, W. F.: Wounds in War. New York: Wm. Wood and Co., 1898.

[8] La Garde, L. A.: Gunshot Injuries. 2d ed. New York: Wm. Wood and Co., 1916.

[9] Wilson, Louis B.: Firearms and Projectiles; Their Bearing on Wound Production. *In* The Medical Department of the U.S. Army in the World War. Washington: Government Printing Office, 1927, vol. XI, pt. 1, pp. 9–56.

[10] Cranz, C., and Becker, K.: Handbook of Ballistics. Vol. I, Exterior Ballistics. Translated from 2d German ed. London: His Majesty's Stationery Office, 1921, pp. 442–450.

[11] Wilson, L. B.: Dispersion of Bullet Energy in Relation to Wound Effects. Mil. Surgeon 49: 241–251, 1921.

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ballistics. Callender and French[12] and Callender[13] used Plasticine as a model for tissues and studied especially the yaw of bullets and the relation of wound damage to the power delivered. They introduced more modern methods of measuring velocities and also obtained records of the pressure changes during the passage of a bullet through Plasticine.

Black, Burns, and Zuckerman[14] have described the enormous damage done by minute fragments of metal from bombbursts. These fragments move with velocities far higher than those of ordinary rifle bullets. Using the spark shadowgraph method and steel spheres, weighing only 53 mg., they were able to imitate the destructive effect of bomb splinters and obtained spark shadow outlines of rabbit legs during passage of the missile. These shadowgrams indicated a large swelling due to the cavity within.

The present work[15] is an attempt to place wound ballistics on a sound quantitative basis. It regards the phenomena observed in wounding of soft tissue as fundamentally like the phenomena which occur when a high-velocity missile enters a liquid. The subject is treated as a branch of underwater ballistics. By means of high-speed motion pictures, spark shadowgrams, and microsecond roentgenograms, measurements have been made of all the changes occurring during passage of a projectile through various parts of the body, and certain constants have been established relating mass, velocity, shape, and other characteristics of the missile to wound phenomena. By means of these constants, it is now possible to predict exactly what damage may be expected from the impact of a known mass moving with any known velocity. The data on which this survey is based are given in later sections, together with reproductions of the photographs and roentgenograms.

The basic purpose of a study of wounding is to obtain data with which to predict the degree of incapacitation (the weeks of hospitalization) which may result from a hit by a missile of given mass (M) moving with a given velocity (V). The incapacitation will naturally depend on the region of the body which is struck. This region in turn will depend on the tactical situation, for example, trench or open warfare, as determined by the military command, which must also decide the length of hospitalization permissible. The probability of a hit is thus a function of the projected body areas exposed. The probable time of hospitalization will vary with the severity of the wound for a

[12] Callender, G. R., and French, R. W.: Wound Ballistics: Studies on the Mechanism of Wound Production by Rifle Bullets. Mil. Surgeon 77: 177–201, 1935.

[13] Callender, G. R.: Wound Ballistics: Mechanism of Production of Wounds by Small Arms Bullets and Shell Fragments. War Med. 3: 337–350, 1943.

[14] Black, A. N., Burns, B. D., and Zuckerman, S.: An Experimental Study of the Wounding Mechanism of High Velocity Missiles. Brit. M. J. 2: 872–874, 1941.

[15] Among the difficult problems encountered during the investigation, particularly in its early stages, was that of assembling under the stress of wartime conditions necessary apparatus and supplies. The beginning of the work would have long been delayed had it not been for the generous loan of equipment by the Ballistics Research Laboratory of the Aberdeen Proving Ground, Aberdeen, Md., and the continued cooperation of members of the staff of this laboratory. We are indebted, also, to the Frankford Arsenal, Philadelphia, Pa., for the loan, until our own equipment was available, of a surge generator, which was essential for the taking of microsecond roentgenograms. Certain items of apparatus originally constructed at the Climatic Research Laboratory of the Signal Corps, Fort Monmouth, N.J., was also made available on loan. The staff of the Princeton University Section, Division 2, National Defense Research Committee, had aided greatly throughout the investigation, both with advice and in respect to securing promptly the needed equipment.—Authors' Note.

particular region and can best be estimated by a military surgeon with considerable field experience. With such knowledge, effectiveness of antipersonnel bombs in terms of casualties can be accurately evaluated, since the distribution of fragment masses and their velocities at various distances from the explosion can be readily determined. This chapter, however, does not propose to estimate time of hospitalization as a result of wounds received from any specific weapon but rather to determine the basic laws governing damage to the various tissues in the body.

METHODS USED IN STUDYING WOUNDING

Army rifles are designed to shoot a 9.6-gram bullet with a velocity of 2,700 f.p.s. and to incapacitate or kill a human target weighing approximately 70 kg. (kilograms). To investigate directly the mechanism of wounding on such a scale would require many large animals and an extensive firing range for the experiments. It is far more economical and fully as instructive to reduce the size of missile and target in proportion. The investigation can then be carried out in any laboratory. For example, a 0.4-gram missile moving 2,700 f.p.s. and striking a 3-kg. animal represents a situation, so far as mass of missile and mass of target are concerned, analogous to those of standard army rifle ammunition and the human body. Therefore, deeply anesthetized cats and dogs have been used for study with steel spheres as missiles (table 25). Fragments of varied shape and corresponding mass and velocity have also been studied.

To supplement the direct experiments on animals, it is highly instructive to study nonliving models. These models simplify the physical conditions and serve to illustrate what can happen in a homogeneous medium. Blocks of gelatin gel, rubber tubes filled with a liquid, or a tank, with Plexiglas sides, filled with water served as targets to record the phenomena connected with the passage of high-velocity missiles. The tank of water, particularly, allows high-speed photography and a complete analysis of all that happens.

TABLE 25.—*Data on steel spheres*

Diameter		Mass		Momentum (MV) (gram-cm./sec., 10^4X) at—		Energy ($\frac{1}{2} MV^2$) (ergs, 10^5X) at—	
Inches	Centimeters	Grains	Grams	500 f.p.s.	4,000 f.p.s.	500 f.p.s.	4,000 f.p.s.
1/16	0. 159	0. 251	0. 0163	0. 0248	0. 199	0. 0194	1. 21
3/32	. 238	. 842	. 0549	. 0836	. 670	. 0654	4. 08
1/8	. 317	2. 00	. 1300	. 1981	1. 58	. 154	9. 65
3/16	. 476	6. 77	. 4397	. 6700	5. 35	. 522	32. 60
1/4	. 635	16. 05	1. 0413	1. 588	12. 70	1. 240	77. 30

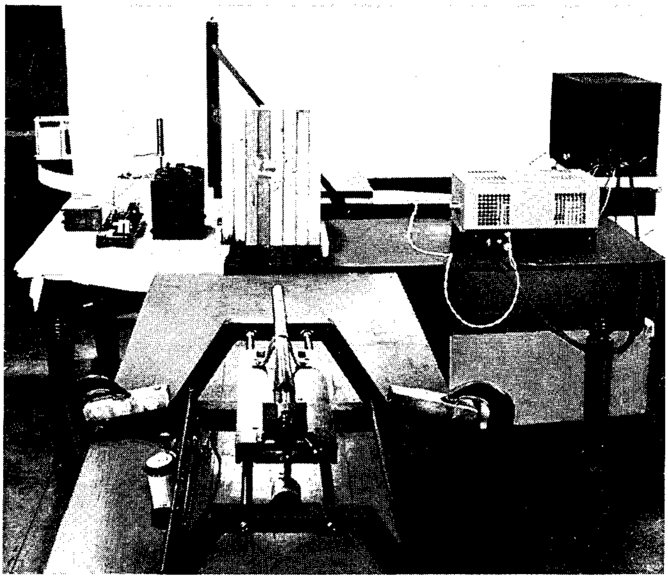

FIGURE 47. *(See opposite page for legend.)*

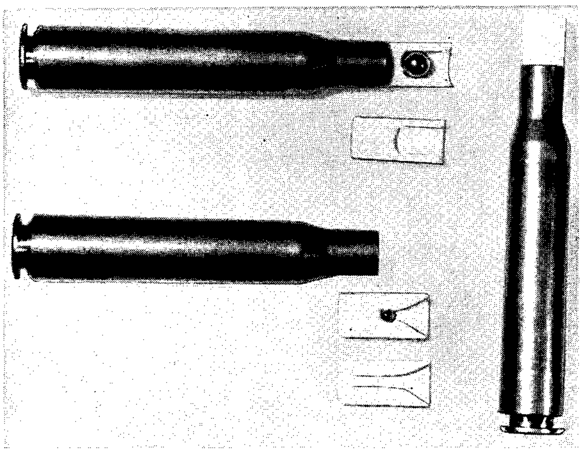

FIGURE 48. *(See opposite page for legend.)*

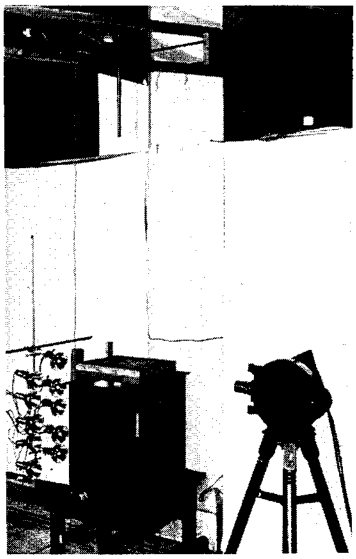

FIGURE 49.
(See opposite page for legend.)

Since many wounds in modern warfare come from steel bomb fragments of small size but of high velocity, a gun was selected which could be used for shooting either fragments or spheres of a mass around 1 gram or less. The gun was a standard caliber .30 Winchester smoothbore which was proof shot with pressures of 65,000 to 68,000 pounds per square inch (fig. 47). The fragment or sphere was carried in a depression in the front of a cylindrical wood sabot about 16 mm. long, split in half longitudinally, and lathe turned to fit the caliber .30 Army standard primed shell (fig. 48). The wooden sabot was satisfactory except for very high velocities (velocities in excess of 3,800 f.p.s.), when it pulverized. In such instances, a similar Textolite plastic sabot was substituted. When the missile emerged from the gun, air resistance separated the two halves of the sabot. These halves were caught by a wooden screen with a hole in the center through which the missile could pass. The shells were filled with fast-burning, 60 mm. mortar powder which was adequate for the sabot and fragments. Variations of velocity were obtained by varying the powder charge from 0.1 gram (1,120 f.p.s.) to 1 gram (4,430 f.p.s.). If care was taken in fitting the sabot, variations in the velocities showed a percentage deviation of only 2.4 for a given powder charge. Figure 49 shows a vertical gun above a water tank with Plexiglas sides to permit high-speed motion picture photography. The lights used for illumination are to the left and the camera to the right.

The velocity of missiles is fairly constant for a given charge of powder, provided the sabots are carefully made to give uniform fit in the ends of the shells. This statement has been checked by three different methods of measuring velocity. One method makes use of the shock wave of the missile in air. This shock wave is allowed to impinge on a metal plate containing a row of small holes. On passing through the holes, the shock wave is converted into a series of sound waves whose shadow is recorded on a photographic plate by a spark discharge. The velocity of the missile is equal to the velocity of sound in air, divided by the sine of the angle between the envelope of sound wave fronts emerging from the holes and the path of the missile.

The well-known Aberdeen chronograph was also used to measure the velocity. This instrument records, on a strip of paper fixed to a drum rotating at a known speed, the time taken by the missile to pass between two stations.

FIGURE 47.—Smoothbore .30 caliber gun mounted in front of wooden sabot screen. The apparatus for spark shadowgram method of velocity measurement is at right and part of an impact record at left.

FIGURE 48.—Wooden sabots used to carry a $\frac{3}{16}$-inch steel sphere (above) and a $\frac{1}{16}$-inch steel sphere (below). At right is the sabot inserted in a .30 caliber army shell.

FIGURE 49.—General view of the tank of water with lights (behind), sabot screen (top), and high-speed motion picture camera (front) for study of phenomena during a shot into a liquid. The gun pointing vertically downward is attached to a beam above the tank. The bright spot of light on the left side of the front of the tank is a sodium lamp running on 60 cycle a.c. which records $\frac{1}{120}$-second intervals in the film.

As the missile passes each station (two tinfoil sheets), a contact is made, thereby triggering a spark which perforates the revolving paper. The time interval can then be read as distance between the two perforations.

The third instrument used for recording velocities was the Remington chronoscope. This also necessitates two trigger screens. When the bullet passes one screen, a condenser begins to charge from a source of voltage and when the second screen is passed charging is stopped. The electrical charge on the condenser then represents a certain time interval which the missile has taken to pass between the stations and can be read with a ballistic galvanometer.

High-speed moving pictures were taken either with the Western Electric 8 mm. Fastax camera (fig. 50 A), capable of 8,000 frames per second, or with the Eastman 16 mm. high-speed camera (fig. 50 B), capable of 3,000 frames per second. Both cameras use the optical compensation principle, in which the film moves across the lens continuously and a rotating prism throws successive images on the film with the same speed as the film itself. Trigger devices were necessary to fire the gun at the proper moment by means of an electromagnet, as a 100-ft. roll of 16 mm. film takes only 1.5 seconds to pass across the lens. Time intervals were recorded by photographing a sodium lamp running on 60 cycles a.c. (alternating current). For illumination, banks of 2 to 12 150-watt projection spotlights, run on 220 volts instead of the rated 110 volts, were used. The light of these bulbs was directed on the object or, for transmitted light, illuminated evenly a ground glass plate placed on the rear wall of the tank.

The spark shadowgraph technique for shock wave recording depends upon a change in refractive index of the medium resulting from a change in pressure. The change in refractive index can be detected on a photographic plate as a shadow, if a point source of light is used for illumination. The point source of light used for high-velocity missiles in water was a high-voltage spark from the discharge of a condenser (fig. 51). The spark, whose duration is less than a millionth of a second, is about 5 feet in front of the tank of water through which the missile will pass, and the photographic plate is on the rear wall of the tank. When the bullet breaks a contact in a screen, the spark is triggered through a thyratron controlled high-voltage surge across the spark gap. By means of a delay circuit, any time interval after the breaking of the screen can be selected for the spark shadowgram.

For taking roentgenograms with an exposure of a millionth of a second, the Westinghouse X-ray surge generator, or Micronex, was used. This apparatus requires a special X-ray tube, with a large tungsten target and a cold cathode. The discharge of a bank of condensers through the tube supplies the current of thousands of amperes, lasting less than a microsecond. Voltage can be varied from 180 to 360 kv. (kilovolt), by charging the six condensers (each of 0.04 microfarad capacity) in parallel at 30 to 60 kv. and then discharging in series. A control box makes operation automatic, and a trigger and delay circuit times the X-ray surge for any desired moment, measured in microseconds. The entire outfit is shown in figure 52.

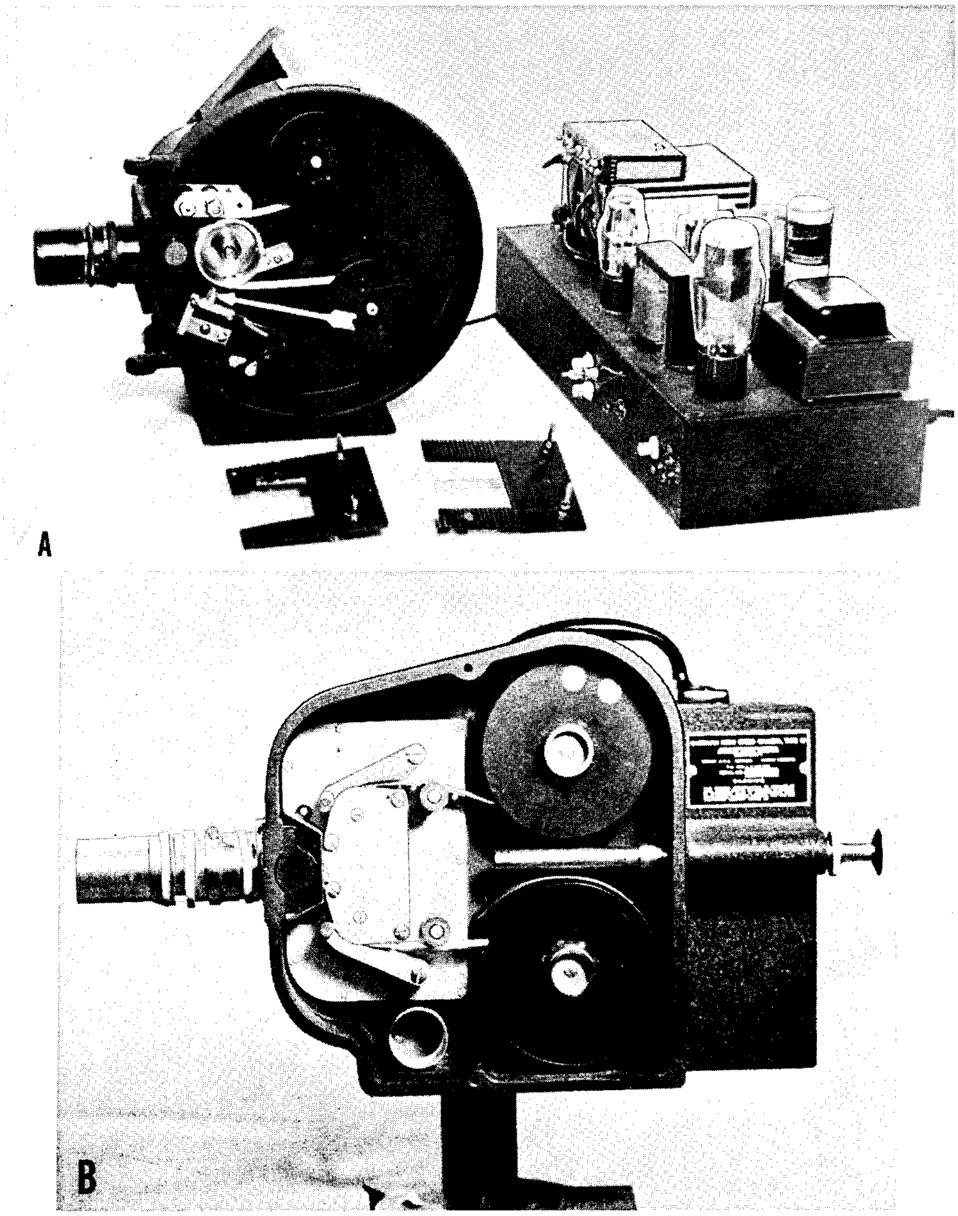

FIGURE 50.—High-speed motion picture cameras. A. Fastax 8 mm. motion picture camera with cover removed to show film looped over sprocket behind rotating prism. The arrow points to a neon lamp which can be used for timing. Two wire grid trigger screens are below camera and a thyratron trigger circuit is at right. B. Eastman 16 mm. high-speed motion picture camera with cover removed to show film reels and rotating prism.

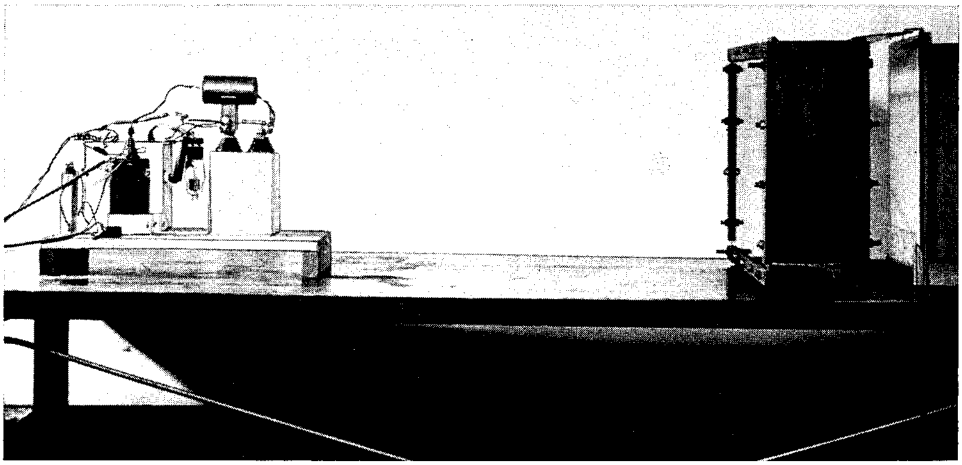

FIGURE 51.—Apparatus for spark shadowgram technique. The water tank with photographic plate behind it is at right. The spark electrodes are in the cylindrical tube (9 cm. long) above the high-voltage condenser at the left. Mounted on the same platform are the high-voltage transformer, rectifying tube, and accessory parts.

For accurately recording pressure changes in an animal, a calibrated piezoelectric tourmaline crystal was used. As a result of changes in pressure, the crystal develops an electrical charge which can be amplified and applied to a cathode ray oscillograph with a single sweep. The phosphorescence of the electron beam on the face of the oscillograph is then photographed. Trigger screens in the proper position before the target were used to start the sweep, whose duration was varied between 130 microseconds and 45 milliseconds. The time calibration was made with a sine wave oscillator. Great precautions must be taken to shield the circuits from electrical and mechanical disturbances which might cause artefacts in the record.

UNDERWATER BALLISTICS AS A GUIDE TO THE WOUNDING MECHANISM

In order to predict the severity of a wound, it is necessary to know what happens when a missile enters the body. The missile's retardation and penetration must be determined and all other phenomena measured quantitatively and related to its mass and impact velocity. Since the material of the body is heterogeneous and opaque, the investigation would be greatly simplified if a homogeneous transparent medium could be substituted and used as a model for the establishment of fundamental laws.

Fortunately, this can be done. The nature of the forces which act on a moving missile will depend on its velocity. For fast missiles, such as have been used in this investigation, these forces are chiefly inertial forces. They depend

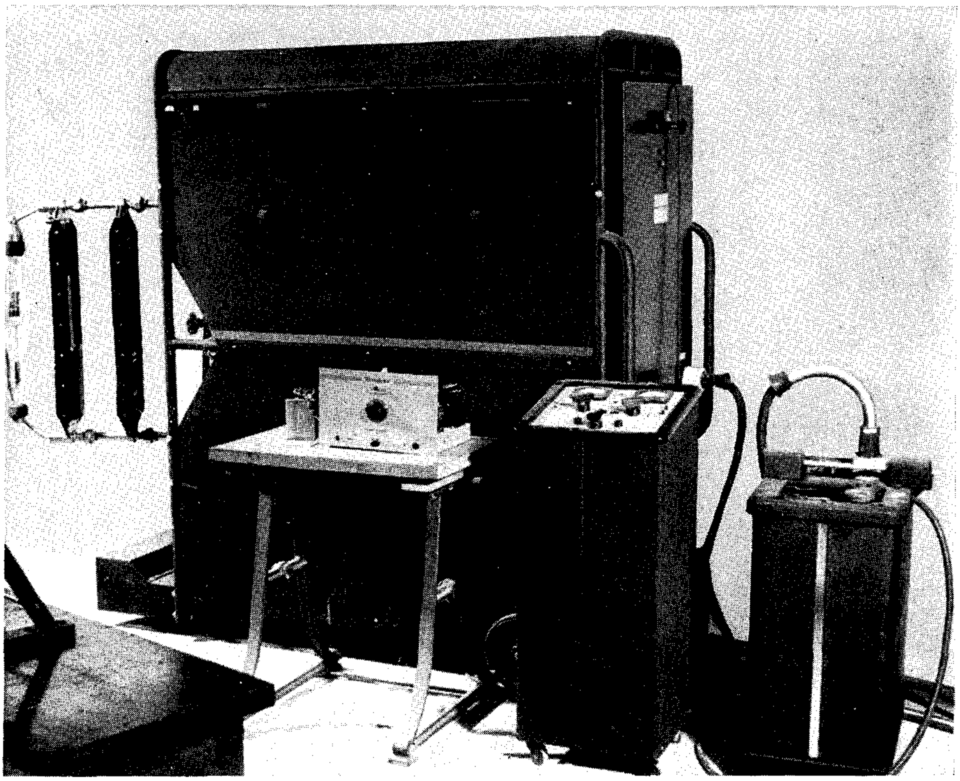

FIGURE 52.—Westinghouse Micronex apparatus for X-ray pictures with exposure of one-millionth of a second. The X-ray tube is at left and the large surge generator containing banks of high-voltage condensers in the middle. In front of the surge generator (from left to right) is the trigger-delay circuit, the control box, and the high-voltage transformer.

primarily on the density of the medium rather than on its viscosity or its structure. Except where there are very strong structural bonds, as in bone, ballistic laws for soft tissue must be similar to those for a liquid or a gel.

Most soft tissues contain about 80 percent water, and it has been found that many of the important events in wounding can be reproduced by shooting into a tank of water. Such a shot is pictured in figures 53 and 54, frames from a high-speed moving picture of a steel sphere entering water with a velocity of approximately 3,000 f.p.s. The large explosive temporary cavity is initially cone shaped but later becomes more spherical and pulsates several times before subsiding to a mass of air bubbles. The cavity behind a sphere shot into water elongates as the sphere proceeds through the water. It also expands radially and then shrinks. Along the narrow neck of the cavity not far behind the sphere, the cavity eventually collapses, creating two cavities. The smaller cavity continues to trail behind the sphere, while the larger one begins to pulsate. The time at which the cavity separation or sealing off takes place

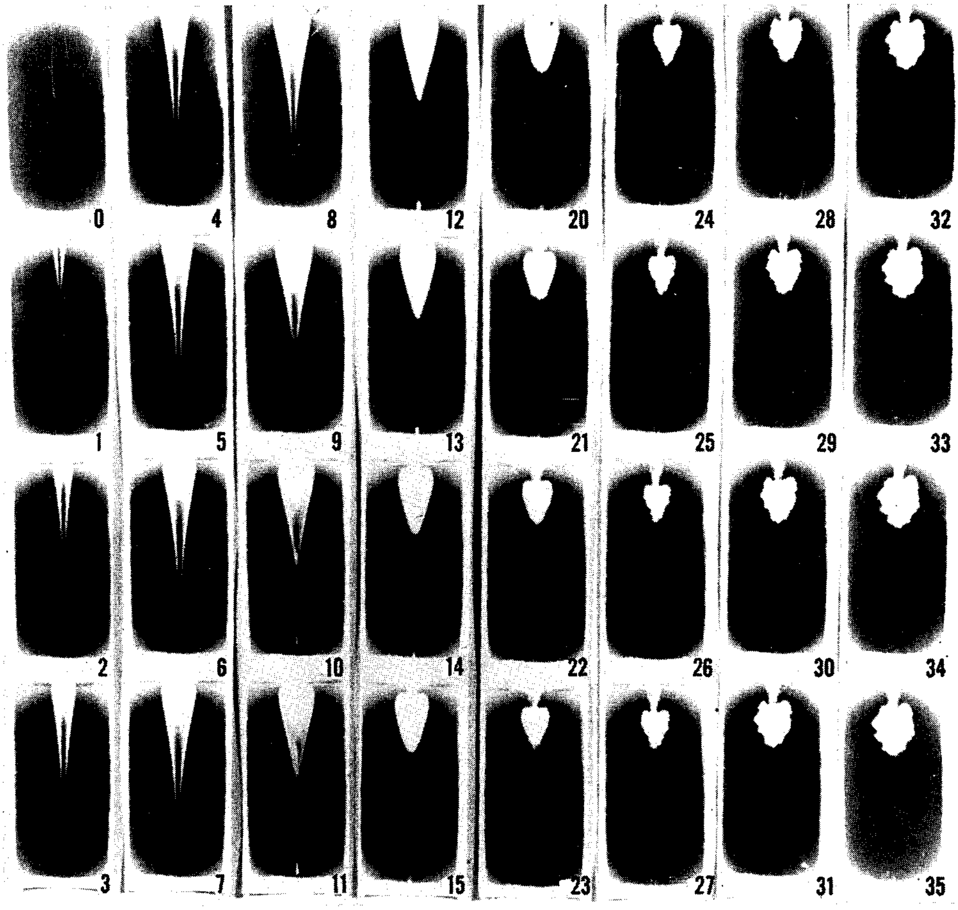

FIGURE 53.—Frames (1,920 per second) from a high-speed motion picture of a 3/16-inch steel sphere entering water with a velocity of 3,160 feet per second. The surface of the water is at the top of each frame and the depth of water 55 cm. Note the initial expansion and later contraction of the temporary cavity to minimum volume at frame 25, with subsequent expansion. (Experiment No. 4, of 4 Mar. 1944.)

depends on the size and density of the bullet. After the cavity behind the sphere separates, the larger main cavity moves slowly in the direction of the sphere. As it pulls away from the surface, a narrow neck develops between it and the surface. The neck soon disintegrates leaving the cavity completely isolated. The isolated cavity continues in slow motion in the direction of the sphere and eventually disintegrates. During all of this process, the cavity undergoes a series of pulsations and grows and shrinks in a regular manner. The pulsations may continue for as many as 7 or 8 cycles and disappear as the cavity disintegrates.

The velocity of radial movement of the water away from the sphere track is about one-tenth that of the sphere velocity. The maximum displacement of

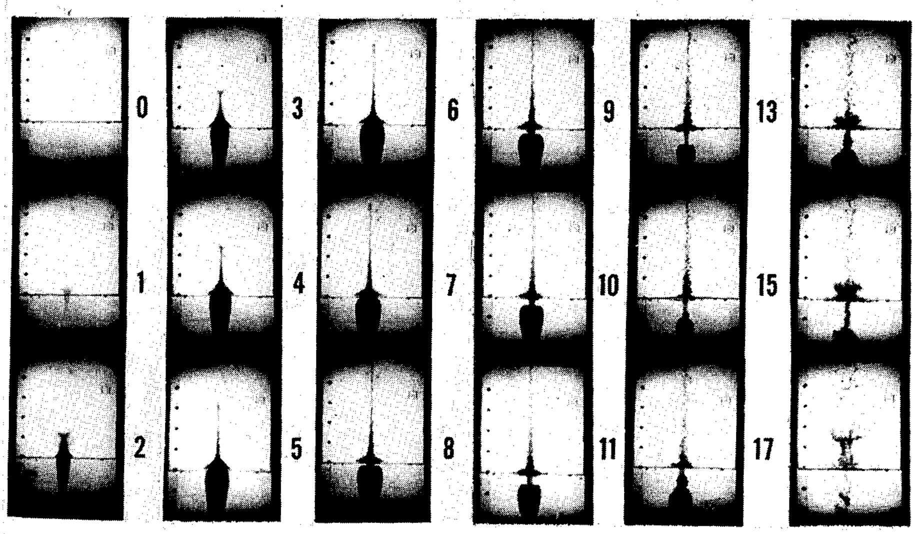

FIGURE 54.—Frames (1,920 per second) from a high-speed motion picture of a ⅛-inch steel sphere (velocity 2,300 f.p.s.) striking the surface of water to show the splash and cavity formation. The dots at left are 5 cm. apart. (Experiment No. 191, of 23 Mar. 1945.)

the cavity wall is proportional to the square root of the kinetic energy of the sphere at any level, and the maximum volume of the explosive cavity is determined by the initial kinetic energy of the sphere. This is expressed as an expansion coefficient which gives the volume of cavity formed for each unit of energy and is equal to 8.92×10^{-7} cc./erg. for water. The period of the first few pulsations of the temporary cavity depends on the cube root of the missile energy and can be expressed numerically (pp. 181–189).

A gel behaves like water, as is illustrated in the frames from a high-speed moving picture of a ⅛-inch steel sphere entering 20 percent gelatin gel with a velocity of 3,800 f.p.s. (fig. 55). The phenomena are nearly the same, even to the splash, although the numerical values of the constants are different. In addition, there is left in gelatin a permanent cavity or track, which is also observed in tissues. The volume of this permanent cavity can be expressed by an excavation coefficient, which gives the volume of cavity formed for each unit of missile energy. The behavior of a rectangular block of gelatin is shown in figure 56.

Rapid retardation of the sphere can be observed in figures 53 and 54, where the tip of the cavity represents the progress of the sphere in equal units of time. This retardation is proportional to the square of the velocity of the sphere, a general law for liquids expressed as a *retardation coefficient*, α. If the material or size of spheres differ, the various quantities are related in the following way: $\alpha = \rho A C_D / 2M$, where C_D is the drag coefficient, ρ the density of the

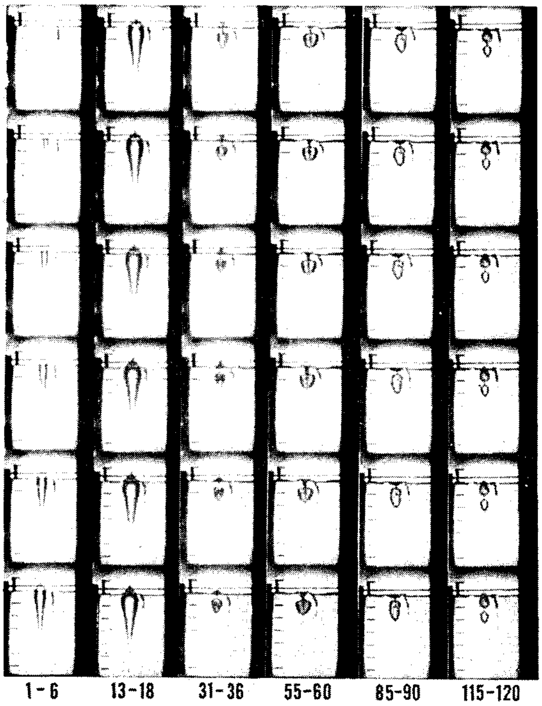

FIGURE 55.—Frames (6,000 per second) from a motion picture of a ⅛-inch steel sphere entering a tank of 20 percent gelatin gel with a velocity of 3,800 feet per second. The scale marks at left are 5 cm. apart. Note the splash and cavity formation which is quite similar to that of water. The permanent cavity of a previous shot shows at right as a vertical line. Frames are numbered below. Temperature: 24° C. (Experiment No. 8G, of 12 June 1944.)

FIGURE 56.—Frames (6,000 per second) from a high-speed motion picture of a gelatin block shot from right to left with a ⅛-inch steel sphere moving 3,800 feet per second. Note the expansion of the block and the two bubblelike protuberances at entrance and exit sites. The bubbles collapse; then the entrance bubble reappears (frames 18 to 35) and again collapses. The background squares are centimeters. (Reel 2, 31 Dec. 1943.)

liquid, M the mass, and A the sphere projected cross-sectional area. For water $C_D=0.297$ and for 20 percent gelatin at 24°C., $C_D=0.350$.

If the missile is a fragment instead of a sphere, the projected area will change as the fragment turns. Hence, the velocity in the water will vary in an irregular manner. The retardation coefficient, the drag coefficient, and the energy delivered to the water will all differ during the advance of the fragment. Turning of the fragment thus leads to the formation of irregular temporary cavities, as shown in figure 57. The cavity is widest when a fragment moves broadside and smallest when the movement is head on.

The velocity squared law holds for spheres in water until the velocity becomes very small. It is difficult to speak of a penetration distance in water. In a gel, however, after decrease to a certain critical velocity V_c, another retardation law is obeyed. Structural bonds and viscous forces quickly bring the sphere to a stop at a definite penetration distance (pp. 227–230).

The pressure on the front of a sphere moving through water is proportional to the square of the velocity V and is numerically equal to $\frac{1}{2}\rho V^2 C_D$. For the shot illustrated in figure 53, the pressure at impact is about 1,500 atmospheres, and the water in front of the sphere is compressed and its refractive index changed. This region of compression at the surface of the water moves away as a spherical shock wave, with a velocity slightly greater than sound in water (4,800 f.p.s.). Spark shadowgrams showing the successive movements of the shock wave are reproduced in figure 58. Each wave consists of an instantaneous rise in pressure to a peak, with an approximately logarithmic fall behind. A pressure time curve for a shock wave is reproduced in figure 59. For the shock wave of figure 59, the peak pressure 10 cm. from the surface is 40 atmospheres and the half decay time about 30 microseconds. The peak intensity of a shock varies directly as the equare of the impact velocity and the projected area of the missile and inversely as the distance from the water surface; it is independent of the density of the missile. Shock waves are reflected from surfaces as either pressure or tension waves, depending on the wave velocity in the material and the density of the material.

Behind the shock wave, the pressure distribution in the water is complicated and continually changing. The very high pressure region in front of the sphere can be visualized by inspection of figure 60, a spark shadowgram of a 3/16-inch steel sphere moving in water behind a grid of lines on a Plexiglas plate. The distortion of the lines in front and at the sides of the sphere is due to a change of refractive index, resulting from compression of the water. Later on, much lower and slower pressure changes, with a phase of decreased pressure, appear around the temporary cavity. A record of these slower pressure changes connected with pulsation of the cavity is shown in figure 61 and the corresponding motion picture of the shot in figure 62.

All the events just cited—shock waves, cavity formation, movements of the medium, and pressure changes—occur when a high-velocity sphere enters soft parts of the body. A retardation coefficient, a drag coefficient, and ex-

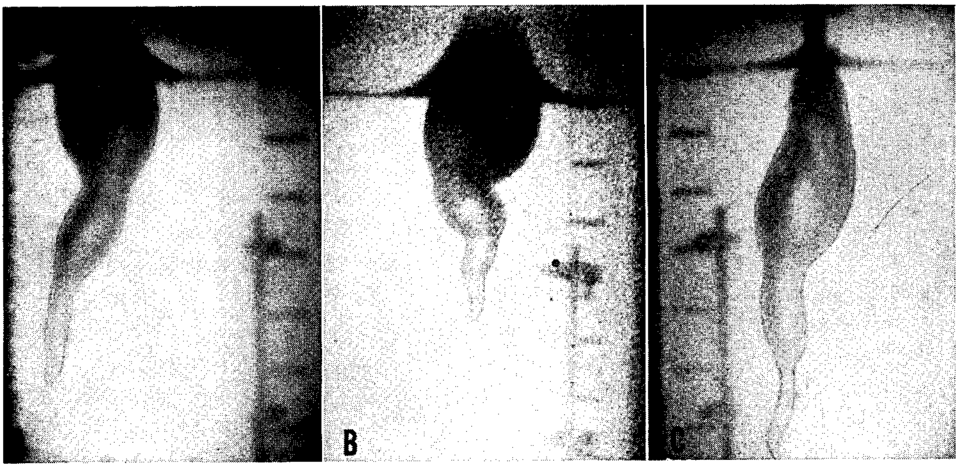

FIGURE 57.—Irregular temporary cavities formed in water by fragments which rotate during penetration. A. A cylinder striking broadside. B. A disk striking broadside. C. A cylinder striking head on, then turning broadside, and finally head on before slowing down. Note that the width of cavity at any level reflects the projection area of the cylinder. Similar cavities occur in tissues when fragments penetrate. Scale marks are 5 cm. apart.

pansion coefficient (of the temporary explosive cavity) and an excavation coefficient (of the permanent cavity) can all be given numerical values.

Among tissues, the numerical constants vary slightly. They differ somewhat from those of water or gel because (1) tissues vary greatly in structural makeup and (2) the body is enclosed in a layer of elastic muscle and skin, rather than the fairly rigid walls of a tank, as in the case of experiments with liquid mediums. Wound ballistics is actually a special branch of underwater ballistics. The remarkable similarity of the phenomena in tissues and in water will be brought out in the following sections.

THE WOUND TRACK OR PERMANENT CAVITY IN MUSCLE

The passage of a high-velocity missile through soft tissues results in the immediate formation of an explosive or temporary cavity many times larger than the missile. After the passage of the missile, the large temporary cavity decreases in volume and a much smaller permanent cavity remains. The size of the permanent cavity is undoubtedly governed by the size of the temporary cavity, which, in turn, is dependent on the size of the missile, as well as on the nature of the tissues involved.

Small, high-velocity steel spheres passing through soft tissue, such as the thigh of a cat, produce rather small entrance and exit holes (fig. 63). The entrance hole produced by a $\frac{4}{32}$-inch steel sphere striking the thigh with a velocity of 3,000 f.p.s. is shown in figure 63A. The exit hole made by this same

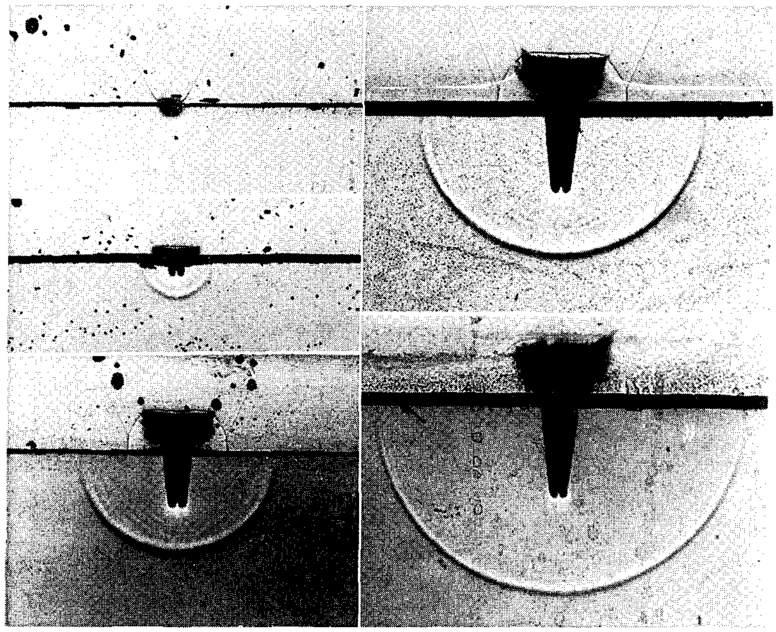

FIGURE 58.—A series (S68, S31, S71, S90, and S21) of spark shadowgrams of ⅛-inch spheres taken at successively longer time intervals after the sphere has hit the water surface. Note how the shock wave, moving 4,800 f.p.s. leaves the retarded sphere behind. The striking velocity in all shadowgrams is 3,000 f.p.s. except in the second where it is 1,772 f.p.s.

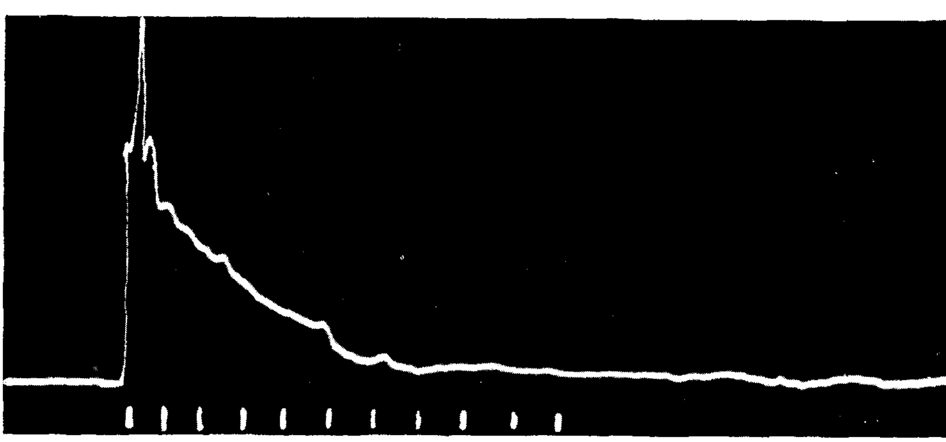

FIGURE 59.—A pressure-time record of a shock wave resulting from impact on the surface of water of a $\frac{3}{16}$-inch steel sphere moving 3,000 f.p.s. The crystal gage was 6 inches from the point of impact, at a 45° angle with the missile path. The time marks are 20 microseconds apart. The peak pressure is 600 pounds per square inch. (Experiment No. 41g, July 1945.)

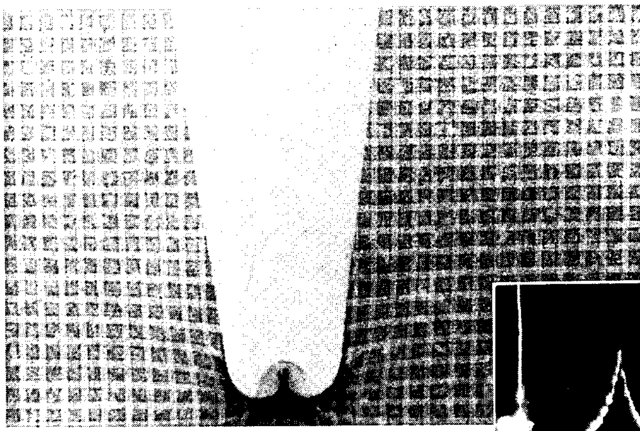

FIGURE 60. *(See opposite page for legend.)*

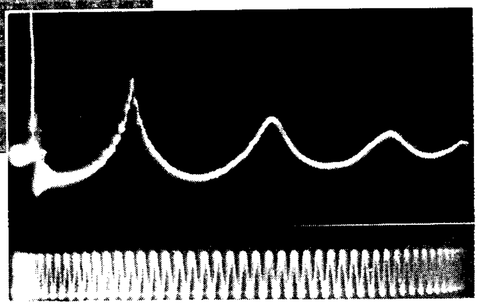

FIGURE 61. *(See opposite page for legend.)*

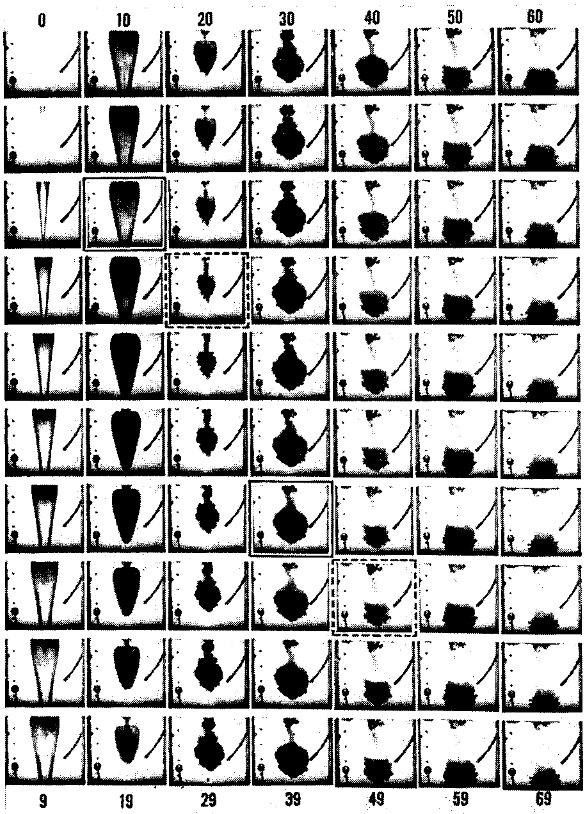

FIGURE 62. *(See opposite page for legend.)*

sphere is shown in figure 63B. In general, exit holes produced by spheres are smaller than entrance holes, because of the decreased velocity of the sphere after it has traversed the thigh. In many cases, the exit hole in muscle is slitlike as contrasted with the circular entrance hole. This slitlike opening is due to the fact that the muscle fibers split apart along their long axes.

The size and configuration of the entrance and exit holes produced by an irregular fragment is dependent on the orientation of the fragment at the instant it enters or emerges from the tissues (fig. 64). The entrance hole made by a small elongate steel fragment (mass 612 mg.) which struck the thigh with a velocity of approximately 3,000 f.p.s. is shown in figure 64A. Yaw cards showed that the fragment struck the thigh broadside, inflicting a very large wound. Had the missile presented a smaller surface to the tissues at the time of impact, a much less severe wound of entrance would have resulted.

A microsecond roentgenogram showed that this same fragment emerged from the thigh oriented along its long axis. Hence, the exit hole is comparatively small, as is shown in figure 64B.

The approximate size and configuration of the wound track or permanent cavity can be determined in several ways. These include (1) roentgenograms of the tissue made immediately after each shot, (2) exploration and dissection of the wound, and (3) reconstruction of the cavity from thin (1–2 mm.) sections of the tissues.

Study of the wound track from roentgenograms (fig. 65) reveals that the permanent cavity formed by the passage of a steel sphere through the thigh is

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FIGURE 60.—Enlargement of a spark shadowgram of the region around a 3/16-inch steel sphere (impact velocity 3,800 f.p.s.) which has penetrated 5 cm. of water. The high pressure near the missile is revealed by the distortion of a 1 mm. grid placed between spark and sphere. (Experiment No. P105.)

FIGURE 61.—A record of pressure changes in a tank of water during penetration of a 3/16-inch steel sphere with a striking velocity of 3,800 f.p.s. The first peak at left is that of the shock wave pressure. The first, second, and third peaks corresponding to three minimum cavity volumes are well marked. Note the subatmospheric pressures below the baseline. The high-frequency (3,000 per second) pressure excursions in the first third of the record are due to vibrations of the steel frame of the tank. One vertical division represents a pressure of 13.1 pounds per square inch. The time record is 1000 cycles. (Experiment No. 3, of 8 Jan. 1946.)

FIGURE 62.—Frames (2,120 per second) from a high-speed motion picture of a 3/16-inch steel sphere entering a tank of water with a velocity of 3,000 f.p.s. The formation behind the sphere of a large cone-shaped temporary cavity which later becomes nearly spherical and pulsates is apparent. Frames are numbered at top and bottom. The first maximum volume is in frame 12, the first minimum in frame 23; the second maximum is in frame 36 and the second minimum in frame 47. The dots to the left are 5 cm. apart. The pressure record for this particular shot is reproduced in figure 61. The crystal gage is visible at the end of the slightly curved line at right of each frame. (Experiment No. 3, of 8 Jan. 1946.)

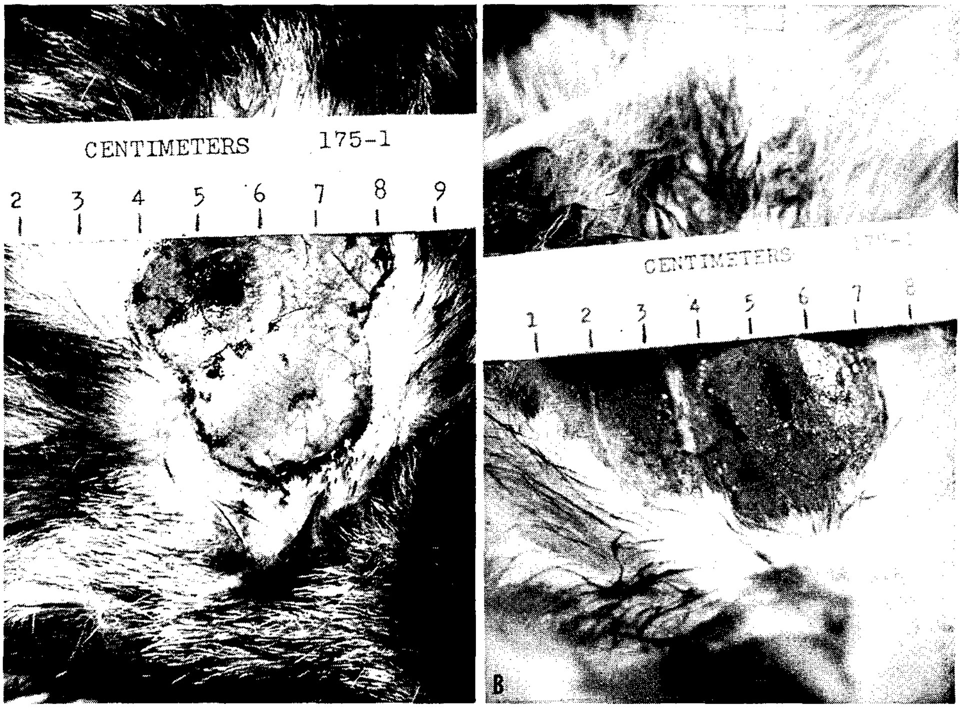


FIGURE 63.—Muscle of cat thigh with entrance and exit holes produced by a 4/32-inch steel sphere with a striking velocity of 3,000 feet per second. A. Entrance hole. B. Exit hole.

somewhat fusiform in shape, having its greatest diameter in the central portions of the thigh. This is illustrated by the roentgenogram shown in figure 65A.

This simple configuration of the permanent cavity is quite often modified by the fact that individual muscles are blown apart along fascial planes as a result of the passage of the missile. These newly created spaces tend to become a part of the permanent cavity and to give it an irregular pattern as shown in figure 65B.

This same type of fusiform cavity is produced when a small high-velocity steel sphere is fired through a block of 20 percent gelatin gel (fig. 66A). The permanent cavities formed by the passage of several 4/32-inch steel spheres through a block of gelatin gel are shown in figure 66B.

Dissection of the wound track in the thigh reveals that the permanent cavity is largest near the center of the thigh and smallest at the points of entrance and exit of the sphere. This fact is illustrated by the thigh shown in figure 67. Figure 67A shows the entrance hole in the thigh of a cat made by a 4/32-inch steel sphere which struck the thigh with a velocity of 3,800 f.p.s. Figure 67B shows the much larger cavity deeper in the tissues of this same thigh. These photographs demonstrate clearly that the small wound of entrance gives no true picture of the amount of damage produced deeper in the tissues.

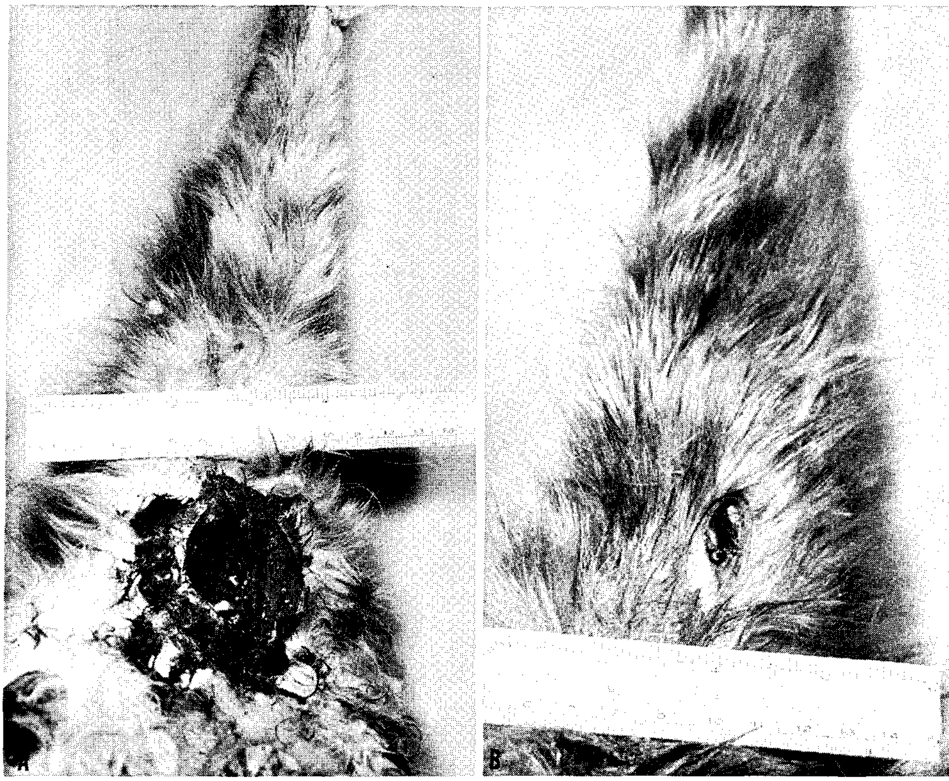


FIGURE 64.—Muscle of cat thigh with entrance and exit holes produced by a small steel fragment which struck the thigh broadside. The dimensions of the fragment were 14 x 5 x 2.5 mm.; the mass of the fragment, 612 mg. The impact velocity of the missile was approximately 3,000 feet per second. A. Entrance hole. B. Exit hole. The fragment emerged from the thigh oriented along its long axis.

The most exact method of determining the size and configuration of the permanent cavity is by a study of serial sections of the tissues cut in a plane at right angles to the path of the missile. A representative set of these sections, each approximately 2 mm. thick, is shown in figure 67C.

Study of a number of sets of serial sections reveals that the permanent cavity in the thigh actually consists of a series of fusiform cavities. This manner of cavity formation is related to the anatomy of the thigh muscles. It appears that as a sphere traverses the thigh a permanent fusiform cavity is formed in each of the larger muscles. The permanent cavity left in the intermuscular connective tissue is quite small, probably because of the elastic properties of this type of tissue. Thus, the permanent cavity or wound track in the thigh is really a series of fusiform cavities, individual muscles giving rise to what might be called a scalloped wound.

Essentially, this same type of behavior can be obtained by firing a high-velocity steel sphere through a series of three blocks of gelatin gel, separated by

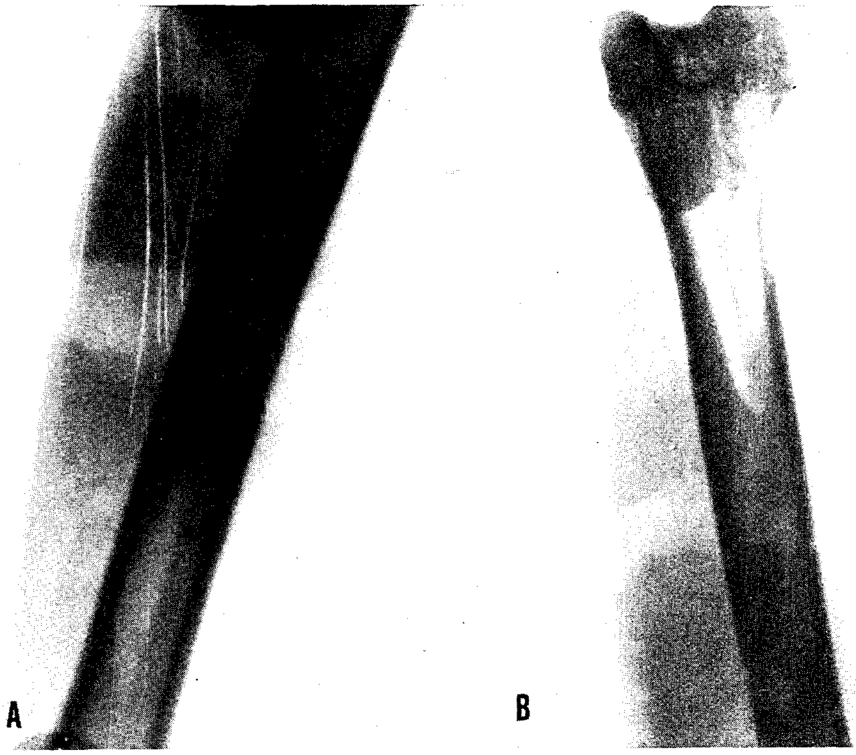


FIGURE 65.—Roentgenograms of thigh of cat showing permanent cavity (light area) left in the tissues after the passage of a 4/32-inch steel sphere whose impact velocity was 3,000 feet per second. A. Roentgenogram (No. 43) shows the fusiform-shaped permanent cavity. B. Roentgenogram (No. 200) shows irregular shape of the cavity.

several sheets of cellophane to simulate the intermuscular fascia. The results of this experiment are shown in figure 68. The sphere passed from right to left in the photograph. This photograph, taken immediately after the shot, shows that fusiform cavities are formed in each block, the size of the cavity decreasing as the velocity of the sphere decreased from block to block. It is not proposed that the behavior of the gelatin block system is precisely identical with that of muscle and fascia, but the general characteristics of the cavities in the two cases are quite similar.

The shape and size of the temporary cavity is often modified by the fact that the cavity may come in contact with a rigid structure, such as bone. Then, as the large temporary cavity continues to expand, soft tissues are pulled away from the bone, and these tissues fail to regain their normal position after the collapse of the temporary cavity. This type of behavior is illustrated by the roentgenogram shown in figure 69.

The question of what becomes of the mass of tissues which originally occupied the site of the permanent cavity is a significant one. High-speed

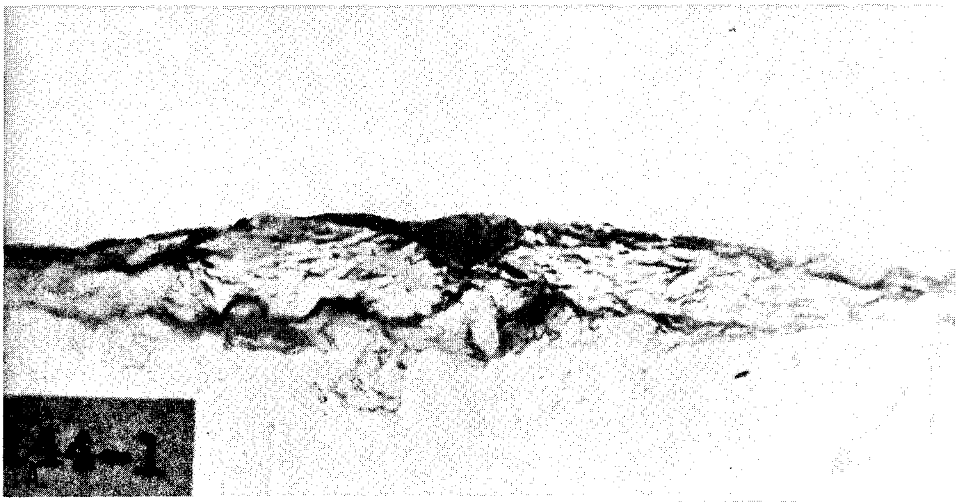
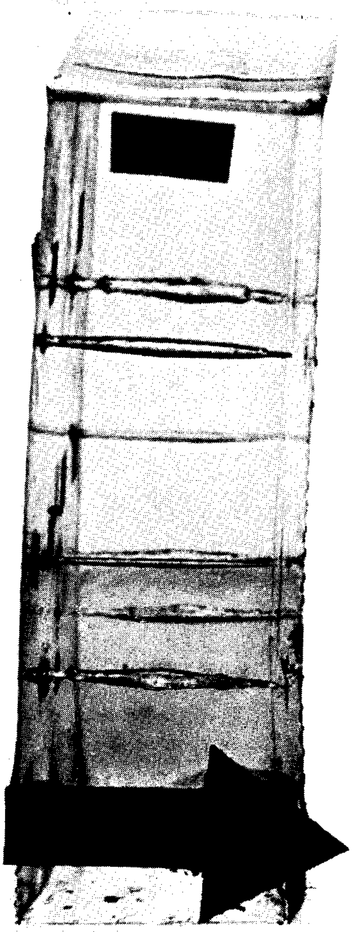


FIGURE 66.—Blocks of 20 percent gelatin gel. A. Block of 20 percent gelatin gel showing the permanent cavity left after the passage of a 4/32-inch steel sphere whose impact velocity was 3,000 f.p.s. Note the similarity of this cavity to that shown in the thigh in figure 65A. B. Block of 20 percent gelatin gel showing the fusiform permanent cavities left after the passage of several 4/32-inch steel spheres whose impact velocities were approximately 2,400 f.p.s.



B

motion pictures and spark shadowgrams show clearly that large amounts of material are lost to the outside during the passage of the missile. This is easily demonstrated by the spark shadowgrams shown in figure 70, of a high-velocity steel sphere passing into a tank of water. The penetration of the missile brings about a marked "splash" at the point of entrance, with the water moving backward at a high velocity. The splash which occurred at the point of exit of a 4/32-inch steel sphere in a block of Plasticine is shown in figure 71.

In cases where complete perforation of an object is obtained, large amounts of material are thrown out at both the points of entrance and exit of the sphere.

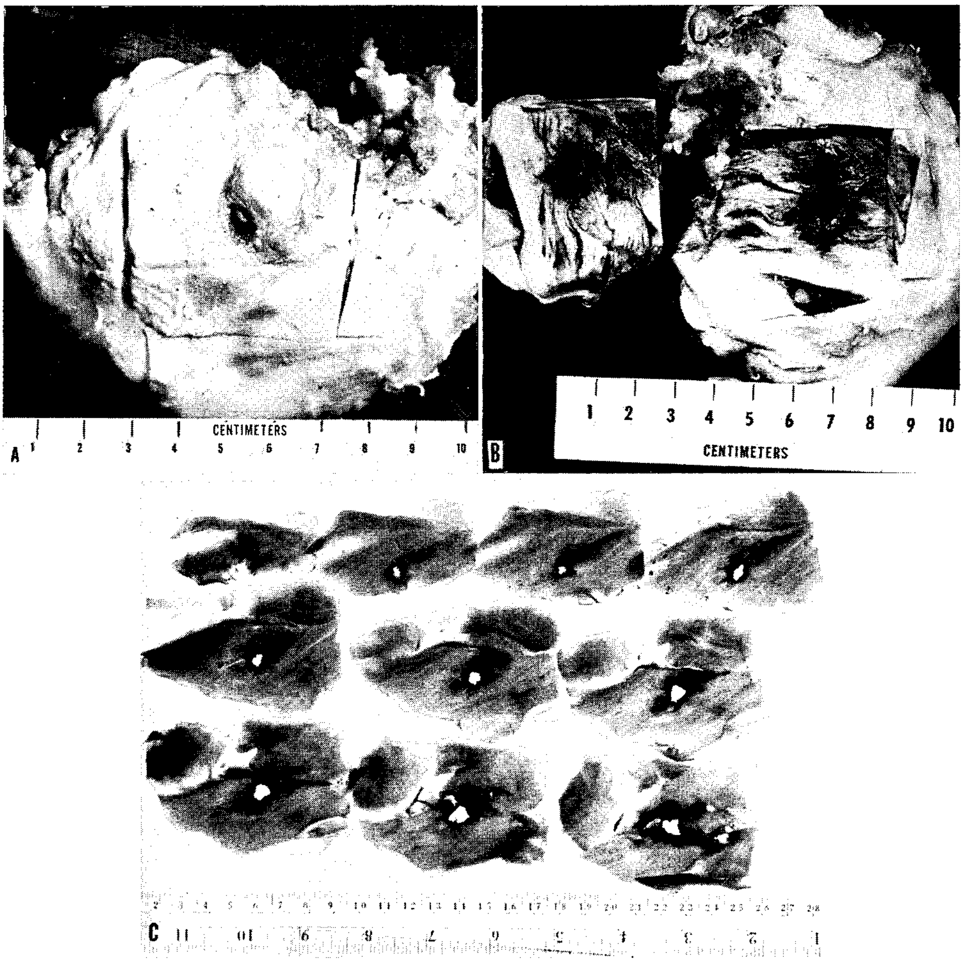


FIGURE 67.—Photographs of soft tissues of the thigh of a cat. A. Relatively small entrance hole made by a $\frac{5}{32}$-inch steel sphere which struck the thigh with a velocity of 3,800 feet per second. B. Tissue shown in A dissected open to show the much larger permanent wound cavity deeper in the tissues of the thigh. C. Serial sections of the soft tissues, cut in a plane at right angles to the path of the missile. Note the permanent cavity and the dark area around it filled with extravasated blood.

This is clearly shown in figure 72, a spark shadowgram of a block of gelatin gel taken immediately after the passage of a $\frac{5}{32}$-inch steel sphere.

The situation in soft tissues of living animals appears to be very similar to that described for a gel. Figure 73 is a spark shadowgram of the thigh of a cat, taken immediately after the passage of a $\frac{5}{32}$-inch steel sphere. A definite splash has occurred at the point of entrance of the missile, and materials are flying out at a high velocity. Large amounts of material are also being

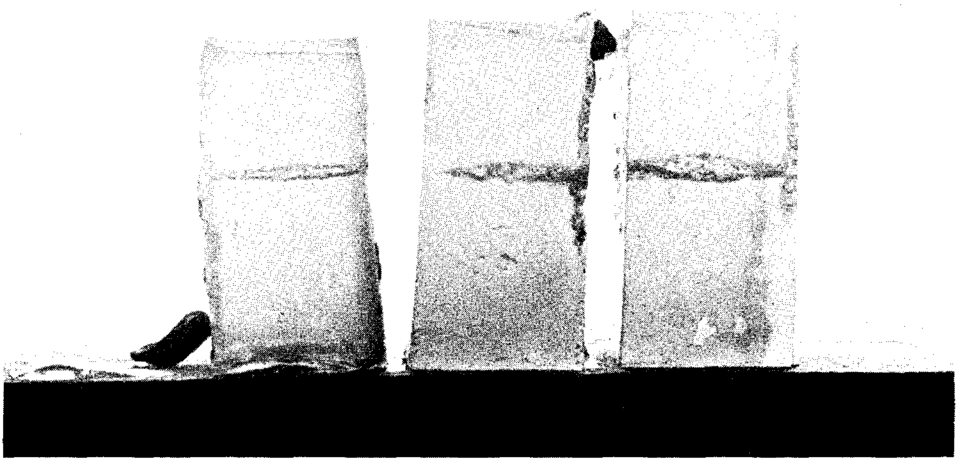


FIGURE 68.—Photograph of three blocks of 20 percent gelatin gel taken after the blocks were traversed by a $\frac{4}{32}$-inch steel sphere whose initial impact velocity was 3,000 f.p.s. The sphere passed from right to left in the photograph. Note that fusiform cavities have formed in each block, the size of the cavity decreasing as the velocity of the sphere decreased from block to block.

swept out by the missile as it emerges at the left. The loss of materials at the points of entrance and exit of a missile can be demonstrated in shots through the abdomen and excised organs, such as the brain, liver, and kidneys.

THE EXPLOSIVE OR TEMPORARY CAVITY IN MUSCLE

A missile entering soft tissues at a relatively high velocity produces a temporary or explosive cavity of large dimensions. The cavity, at its maximum size, has a cross-sectional diameter many times that of the permanent cavity, which remains after the temporary cavity has collapsed. The temporary cavity persists for a relatively short time, reaching its maximum size in less than a millisecond and lasting for not more than several milliseconds.

The penetration of a small high-velocity steel sphere into a large mass of butcher meat results in the formation of an initially cone-shaped cavity, very similar to the cavity formed by the same type of missile in water (pp. 152–158). Figure 74A is a microsecond roentgenogram showing the large cavity formed in butcher meat by a $\frac{4}{32}$-inch steel sphere which struck the meat with a velocity of 2,800 f.p.s. and had penetrated a distance of 10.2 cm. when the roentgenogram was made. The sphere eventually perforated the block of meat completely, so that this roentgenogram does not show the final configuration of the temporary cavity. Its chief value lies in demonstrating the striking similarity

FIGURE 69.—Roentgenogram (No. 171) of the thigh of a cat taken immediately after the passage of a 5/32-inch steel sphere whose impact velocity was 3,000 f.p.s. Note the outlines of the permanent cavity (light area) and the manner in which it has "blown out" to the femur. Also note that the femur is fractured, although it was not struck by the sphere.

of the early cavity in animal tissue and that in water, shown by the microsecond roentgenogram in figure 74B.

The greatest mass of muscle in an intact animal is the thigh. In the largest dogs used in this study, the thigh was from 6 to 9 cm. in its greatest dimension. A single microsecond roentgenogram of a thigh can show only one particular stage in the development of the temporary cavity. However, by varying the interval between the time at which the missile struck the thigh and the time at which the roentgenogram was made, it is possible to obtain a series of pictures which together will show successive stages in the development of the cavity. A series of five such microsecond roentgenograms, showing the development of the cavity in the thighs of dogs, is shown in figure 75. In each case, the thigh was struck by a 5/32-inch steel sphere whose impact velocity was approximately 2,800 feet per second.

FIGURE 70.—Spark shadowgraph of a $\frac{3}{32}$-inch steel sphere passing into a tank of water. Note the conical-shaped temporary cavity and the backward "splash" of water at the point where the sphere entered the water.

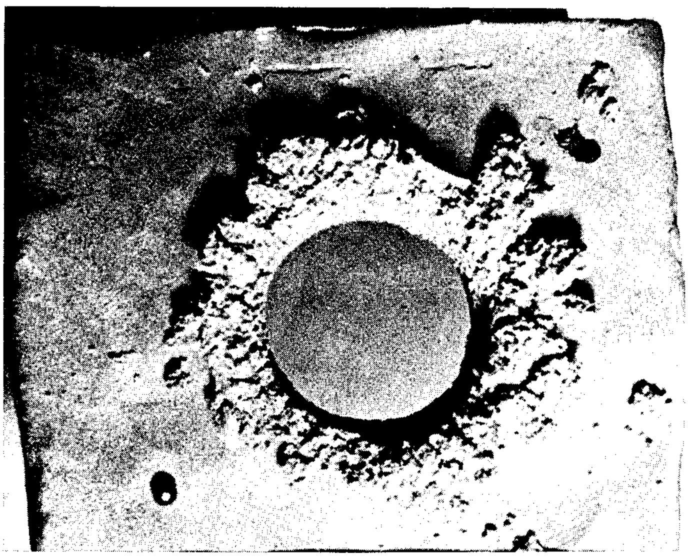


FIGURE 71.—Photograph of a block of Plasticine showing the cavity made by the passage of a $\frac{3}{32}$-inch steel sphere whose impact velocity was 3,000 f.p.s. Compare size of cavity with size of the sphere placed in lower left of block. Note the large amount of material thrown out at the point of exit of the sphere. A similar "splash" also occurred at the point of entrance.

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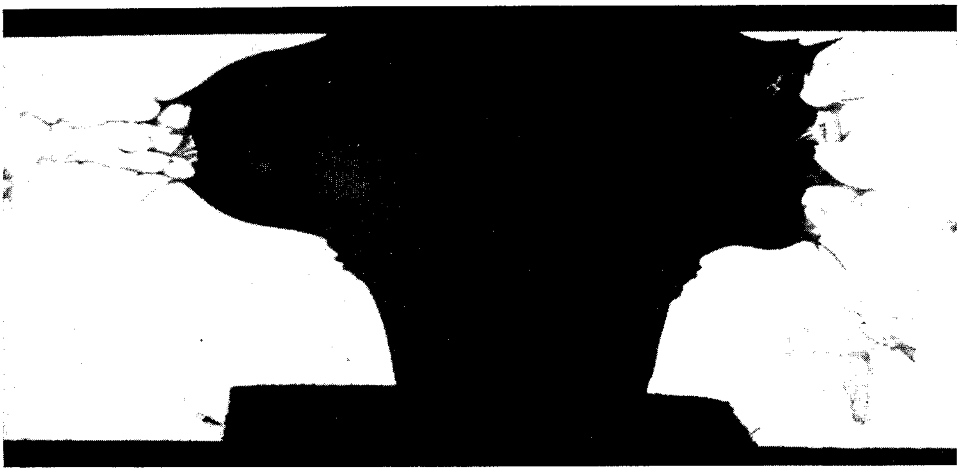


FIGURE 72.—Spark shadowgraph of a rectangular block of 20 percent gelatin gel made immediately after the passage of a $\frac{3}{32}$-inch steel sphere whose impact velocity was 2,800 f.p.s. The missile passed from right to left in the shadowgraph. Note the manner in which the block has expanded and the large amounts of material being thrown out at both the entrance and exit sites.

Figure 75A is a microsecond roentgenogram showing the temporary cavity 56 microseconds after the sphere struck the thigh. A cone-shaped cavity has formed behind the sphere, whose walls are relatively smooth. It is at this stage of development that the similarity of the temporary cavity in animal tissues and in water is the greatest.

Figure 75B shows the cavity 71 microseconds after the sphere struck the thigh. The sphere has emerged from the thigh and has moved several centimeters from it. The conical cavity is expanding, and its walls are becoming somewhat irregular.

The roentgenogram in figure 75C shows a cavity whose age is 139 microseconds. The sphere has now moved out of the field of the photograph to the right. The cone-shaped cavity has continued to expand, and its walls have become very irregular, probably owing to the irregular stretching and tearing of tissues being displaced by the cavity.

Figure 75D shows the cavity photographed 390 microseconds after the sphere struck the thigh. The cavity has expanded still more and has assumed the shape of a prolate ellipsoid. Observation of many of these cavities indicates that a cavity with this configuration is near its maximum size. The cavity shows marked irregularities on its walls, as well as strands of tissue of different densities, which can be interpreted as areas of stretched and torn tissues. The sphere which produced this cavity had an initial energy of 3.7×10^8 ergs (35 ft.-lb.) and lost approximately 85 percent of this energy in producing the cavity.

Roentgenograms made from 600 to 800 microseconds after the sphere struck the thigh show that the cavity, after reaching its maximum size, col-

FIGURE 73.—Spark shadowgraph of the thigh of a cat made immediately after the passage of a 5/32-inch steel sphere whose impact velocity was 3,000 f.p.s. The missile passed from right to left in the shadowgraph. Note the large amount of materials being ejected at both the points of entrance and exit of the missile. Note the similarity to the gelatin block in figure 72.

lapses. Figure 75E shows a cavity whose age is 819 microseconds. The cavity has practically collapsed, and only a small rounded space remains near the center of the thigh. High-speed motion pictures of the exterior of a thigh, such as those of figure 76, show the temporary swelling, indicative of the internal formation of this cavity.

The temporary cavity in the thigh of a cat, formed by the passage of a 5/32-inch steel sphere with an impact velocity of 2,800 f.p.s., is shown in figure 77A. Although this cavity has not reached its maximum size and the sphere did not strike the femur directly, a fracture line has appeared in this bone. Figure 77B is a roentgenogram of this same thigh made before the shot and figure 77C a similar roentgenogram made after the shot. In this latter picture, the permanent cavity is well outlined. This type of "indirect" fracture is dealt with in greater detail on pages 200–204.

All the temporary cavities just described were photographed to show the path of the missile and the cavity in lateral view. Other microsecond roentgenograms show that the cavity formed in soft tissues by a sphere is circular

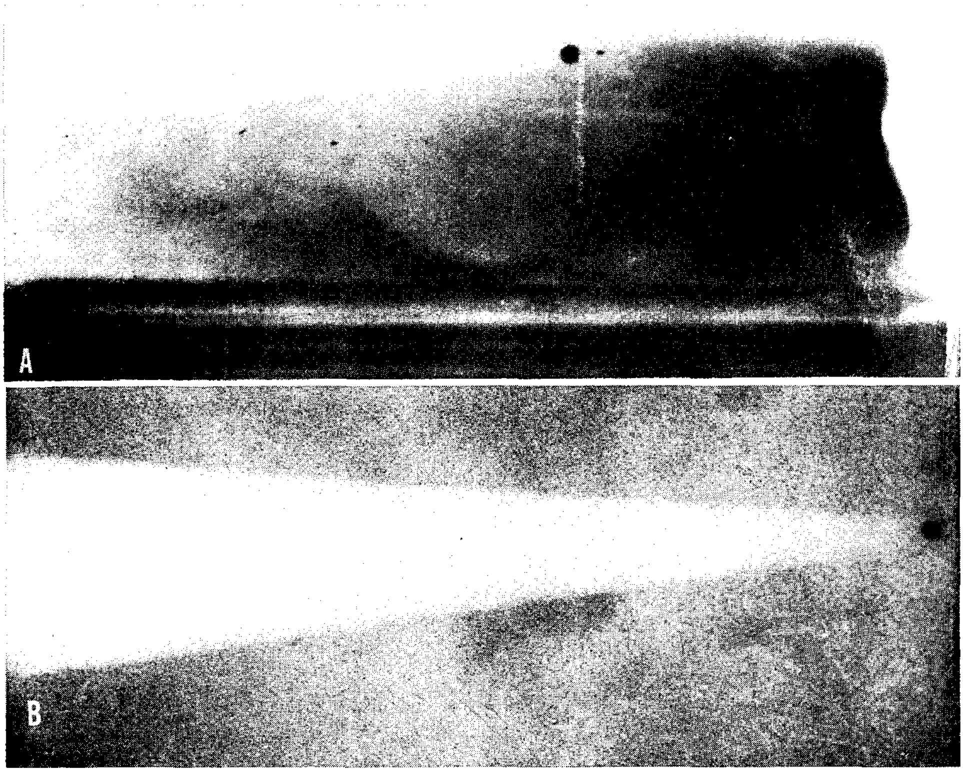


FIGURE 74.—Microsecond roentgenograms. A. Roentgenogram (No. 105) of a $4/32$-inch steel sphere passing through a block of butcher meat. The sphere struck the meat with a velocity of 2,800 f.p.s. Compare with B and note the similarity of the cone-shaped temporary cavity to that formed in water. B. Roentgenogram (No. 25) of a $4/32$-inch steel sphere passing into a container of water.

FIGURE 75.—Microsecond roentgenograms of the thigh of a dog showing the temporary cavity formed by a $4/32$-inch steel sphere whose impact velocity was 2,800 feet per second. A. Roentgenogram (No. 22) was made 56 microseconds after the sphere struck the thigh and shows the cone-shaped temporary cavity formed by the sphere. B. Roentgenogram (No. 18) was made 71 microseconds after the sphere struck the thigh. Note that the sphere has just emerged at the right and that the temporary cavity is expanding. C. Roentgenogram (No. 32) was made 139 microseconds after the sphere struck the thigh. Note the continued expansion of the cavity which results in a stretching and tearing of the tissues. D. Roentgenogram (No. 28) was made 390 microseconds after the sphere struck the thigh. The cavity has assumed the shape of a prolate ellipsoid and is judged to be at its maximum size. E. Roentgenogram (No. 31) was made approximately 819 microseconds after the sphere struck the thigh. Note that the cavity has practically collapsed and only a small cavity remains near the center of the thigh.

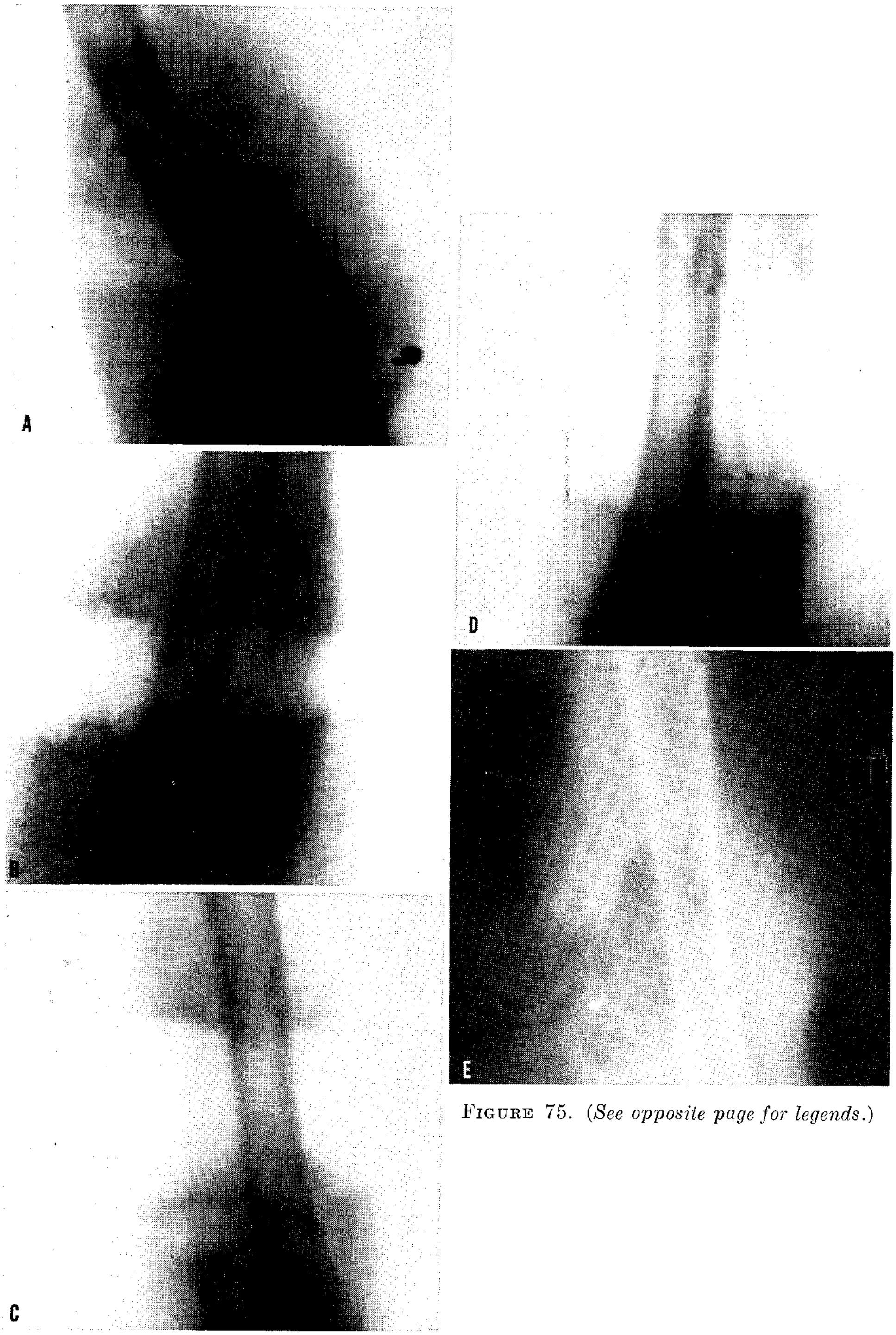


FIGURE 75. (*See opposite page for legends.*)

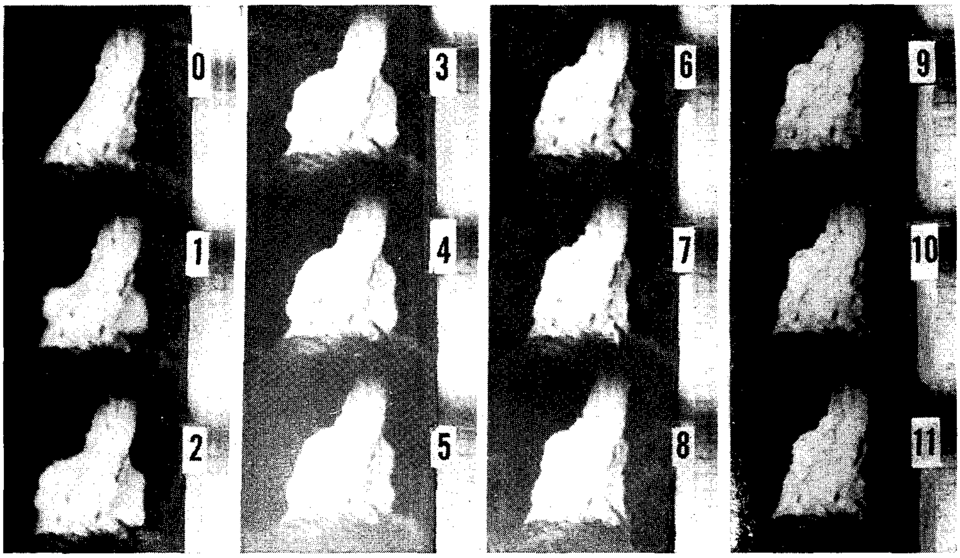


FIGURE 76.—A series of prints from a high-speed motion picture (4,500 frames per second) of the leg of an anesthetized cat, with skin intact, shot with a ⅛-inch steel sphere moving 3,000 f.p.s. The sphere entered from the right and exited from the left side. The foot is up. The temporary swelling, indicating a large cavity within, can be clearly seen. (Reel 11, 6 Jan. 1944.)

when seen in cross section. The latter is well shown in the roentgenogram in figure 78, taken 200 microseconds after the sphere struck the thigh. The small black spot in the center of this photograph marks the point at which the sphere penetrated the X-ray film.

In the case of irregular fragments, the size and configuration of the temporary cavity depends not alone on the energy of the fragment but also on its projected area as it strikes the tissue. The projected area varies along the path of the missile as changes in orientation of the fragment occur. This is illustrated by the microsecond roentgenogram shown in figure 79. The thigh of a cat was struck by a small elongated fragment (originally part of a 75 mm. shell) whose mass was 630 mg. and whose impact velocity was 3,000 f.p.s. The fragment struck the thigh broadside and emerged with the orientation shown in this photograph. The cavity is very large at the point of entry and much smaller near the point of exit of the missile. The femur, struck directly by the missile, was badly shattered.

A second case is shown in figure 80, where a thigh was struck by an elongated fragment made from a small wire nail. The fragment was cylindrical, 11 mm. in length, 2.5 mm. in diameter, and had a mass of 380 mg. Its striking velocity was approximately 3,000 f.p.s. The irregular shape of this cavity indicates that the orientation of the fragment changed slightly as the missile passed through the tissues.

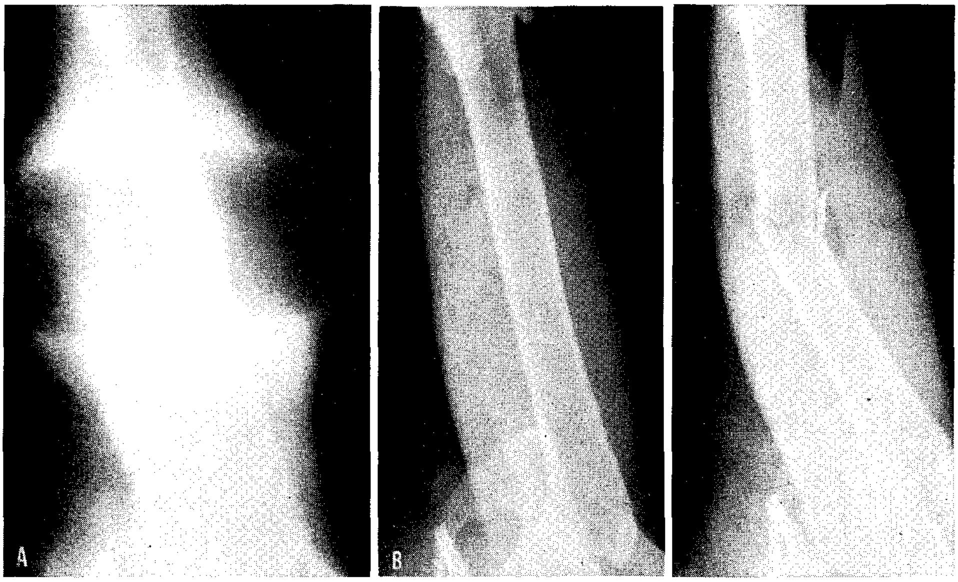


FIGURE 77.—Roentgenograms of thigh of a cat made before and after thigh was struck by a 4/32-inch steel sphere whose impact velocity was 2,800 f.p.s. A. Roentgenogram made 170 microseconds after the shot. Note the expanding temporary cavity and the fracture line appearing in the femur, although this bone was not struck by the sphere. B. Roentgenogram (No. 135) made immediately before the shot. C. Roentgenogram made immediately after the shot. Note the permanent wound track (light areas), which indicate regions where muscles have been separated, and the fractured femur.

The temporary cavities produced by standard .22 caliber ammunition are very similar to those produced by spheres, as long as the bullet remains oriented on its long axis. This is illustrated by the roentgenogram in figure 81. If the bullet wobbles, or in any way changes its orientation, the result is similar to that just described for fragments.

A temporary cavity, very similar to those described in cat thighs, can be obtained by firing a steel sphere through the excised skin of a cat thigh which has been filled either with gelatin gel or with water. The cavity in a gelatin-filled skin is shown in figure 82A and in a water-filled skin in figure 82B. These photographs again emphasize the similarity of the temporary cavities in animal tissues and in the nonliving materials used.

Study and measurement of a large number of temporary cavities show that the total volume of the cavity is proportional to the energy delivered by the missile. Data obtained have made it possible to obtain a value for an expansion coefficient, k. The expansion coefficient, k, in muscle has a value of 80.1×10^{-9} cm.^{3}/erg. This can be restated as follows: For every erg of energy lost by a missile in muscle, there is formed a temporary cavity with a volume of 80.1×10^{-9} cm.^{3}

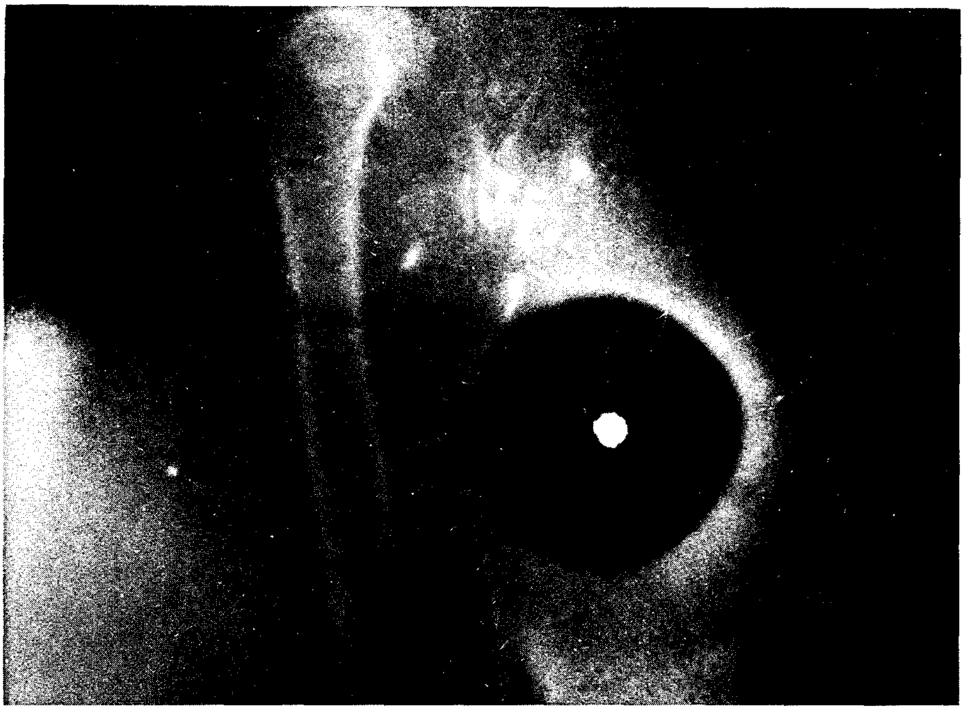


FIGURE 78.—Microsecond roentgenogram (No. 232) of the thigh of a cat showing the temporary cavity formed after the passage of a 4/32-inch steel sphere whose impact velocity was 3,000 f.p.s. The cavity age is 200 microseconds. The sphere was fired in a line parallel to the X-ray beam, and the temporary cavity (dark area) is seen in cross section. Note the approximately circular shape of the cavity.

The relationship of total cavity volume to energy expended can be demonstrated in another way. Steel spheres of two different masses (8/32-inch spheres, mass 1.04 gm., and 4/32-inch, mass 0.130 gm.) were fired through the thighs of cats. The striking velocities of the two spheres were adjusted so that each size of sphere would lose approximately the same amount of energy in passing through the tissues. The striking velocity of the 8/32-inch sphere was approximately 1,500 f.p.s.; that of the 4/32-inch sphere, 3,000 f.p.s. In cases where measured energy losses were approximately equal, the volumes of the temporary cavities produced by the two-sized spheres were likewise approximately equal. An illustration of this equality is shown in figure 83.

The formation of this high explosive cavity results in great displacement and tearing of muscle and connective tissues, rupture of small blood vessels, and stretching and compression of larger blood vessels and nerves. This behavior is sufficient to account for the very serious damage often observed in wounds at a considerable distance from the missile track. A more detailed description will be found on pages 189–200.

FIGURE 79.—Microsecond roentgenogram (No. 277) of the thigh of a cat showing the temporary cavity formed by the passage of a small, irregular fragment of a 75 mm. shell. The fragment is seen emerging from the thigh at the right. Note the irregular shape of the temporary cavity and the fractured femur.

THE EXPLOSIVE OR TEMPORARY CAVITY IN ABDOMEN, THORAX, AND HEAD

Phenomena quite similar to those which have been discussed for muscle occur when a high-velocity missile enters the abdomen, the thorax, or the head. A temporary cavity, filled largely with water vapor, forms behind the projectile. After expanding to a certain volume, the cavity collapses. During the expansion, tissue is stretched and torn, and, following the pulsation and collapse of the cavity, tissue is violently pushed together with additional injury.

Although the general structural makeup of the abdomen is similar to that of muscle, the thorax and head are quite different. The thorax is largely air filled, because of the large volume occupied by the lungs. Its walls are also more rigid than are those of the abdomen, because of the supporting ribs. The head is made up of a brain, essentially liquid, enclosed in rigid cranial walls. The temporary cavity in thorax or head will, therefore, be modified by various secondary conditions, and the expansion coefficient can be expected to be quite different in the three regions.

The chief changes resulting from a shot through the abdomen of a deeply anesthetized cat are shown in figure 84. The two bulges of the temporary cavity on each side are apparent in frames 2 to 4. These bulges later collapse (frames 5 to 14) and then appear again (frame 15) as small, wrinkled projections

FIGURE 80.—Microsecond roentgenogram (No. 264) of the thigh of a cat showing the temporary cavity formed by the passage of a small elongate section of a wire nail. Note the irregular shape of this cavity as contrasted with those formed by spheres.

which later merge with the general violent, twisting movements of the abdomen. A similar type of swelling, indicative of a large temporary cavity within, results from a shot through a rubber tube filled with water (fig. 85). The abdomen behaves like this model liquid system.

The large temporary cavity within the abdomen is revealed in the microsecond roentgenogram of figure 86, triggered just as the cavity is beginning to collapse, as indicated by the slight indentation on each side. In this figure and in figure 87, the intestine has been made radiopaque by barium sulfate. A smaller cavity in process of growth is shown in figure 87A, B, and C, which allows comparison of the abdomen before, during, and after the shot. The increased diameter of the intestine is readily apparent in the center microsecond roentgenogram, probably because of the flattening against the abdominal walls. Note that the barium sulfate has leaked out into the body cavity after the shot, indicating extensive perforation and damage to the intestine, a point corroborated by autopsy.

Microsecond roentgenograms, taken at a time when the second protuberances of frame 15 (fig. 84) have appeared, show no second internal cavity. The collapse of the initial temporary cavity seems to be complete. Since entrance and exit holes in the skin are small and a marked splash of material

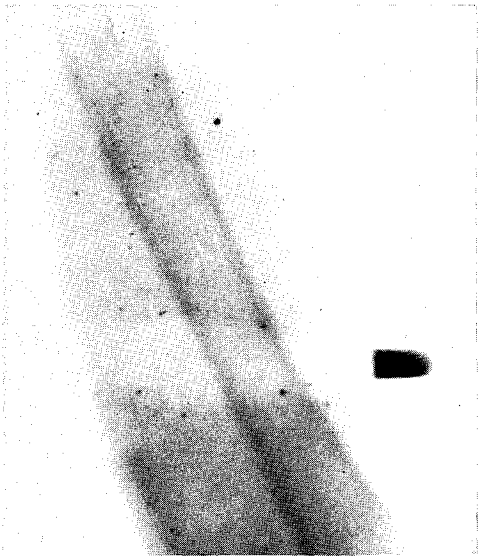


FIGURE 81.—Microsecond roentgenogram (No. 126) of the thigh of a small dog showing the conical-shaped temporary cavity formed by the passage of a .22 caliber long rifle bullet. Note the similarity of this cavity to that formed by a sphere as shown in figure 75.

has been observed to move out from each hole, it is very likely that little or no air can rush into the cavity. The cavity is filled mostly with water vapor, and consequently complete collapse will occur, with only a few small gas pockets undergoing pulsation. In this respect, a shot into the abdomen differs from a shot into a tank of water where the partially air filled temporary cavity (fig. 62) undergoes a series of marked pulsations. If a steel fragment instead of a sphere is shot through the abdomen, irregular temporary cavities appear (fig. 88).

During a shot through the thorax, very little movement is evident (fig. 89). The lack of movement is connected in part with the air-filled lungs, which do not fulfill conditions for cavity formation, and in part to the strong rib-reinforced walls of the thorax. In roentgenograms (fig. 90) giving views before, during, and after the shot, no clearly visible cavity is apparent. Because of the large amount of air in the lungs and the difficulty of distinguishing cavity from air, a clear-cut temporary cavity is hardly to be expected. It is apparent, however, that the heart has been displaced upward and to the right as a result of the shot, so that some type of temporary cavity is presumably formed.

The pressures which accompany a high-velocity missile moving through tissue are enormous (pp. 211–223). Therefore, it is not surprising to find that a steel sphere fired into the head can produce a temporary cavity in brain tissue, despite the apparent strength of the cranium which must resist the pressure. The cavity formed by a missile in the brain of an intact cranium is of finite size, partly because brain tissue is forced through regions of less resistance (such as the frontal sinuses and the various foramina of the skull) and partly because of the stretching of the cranium itself. When the energy delivered is very great, skull bones are actually torn apart along suture lines.

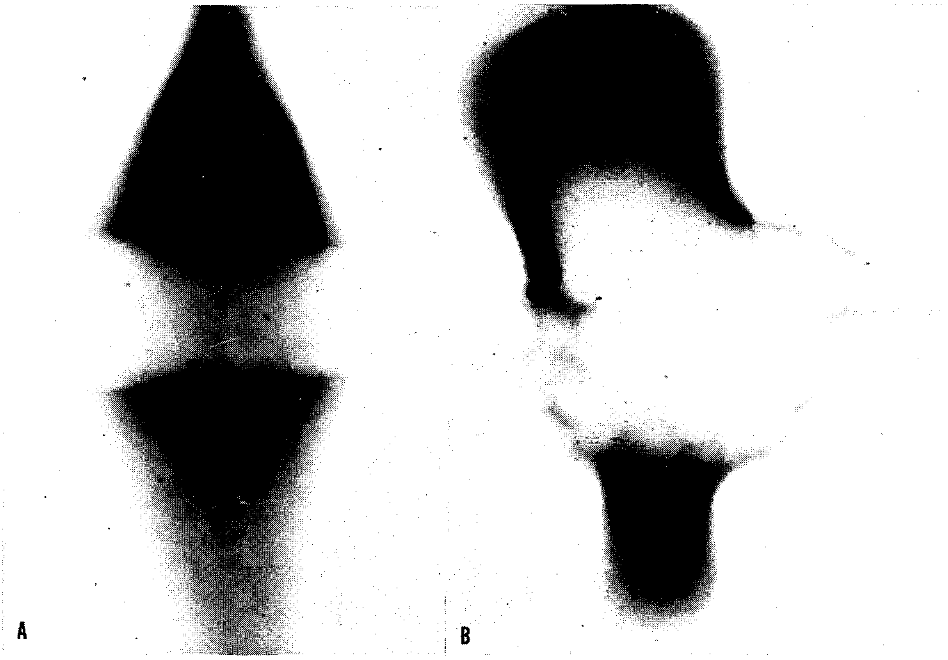


FIGURE 82.—Microsecond roentgenograms of skin of cat thigh, showing temporary cavities formed after passage of a $\frac{5}{32}$-inch steel sphere whose impact velocity was 2,800 feet per second. A. Roentgenogram (No. 147) shows cavity in skin filled with 20 percent gelatin gel. Note the similarity of this cavity to those formed in the thigh as shown in figures 75 and 77. B. Roentgenogram (No. 150) shows cavity in skin filled with water. Note the similarity of this cavity to those cavities formed in animal tissues.

The temporary cavity within the skull is apparent in the microsecond roentgenogram of figure 91, a dog's head perforated by a $\frac{1}{8}$-inch steel sphere moving 4,000 f.p.s. Figure 92 is a similar microsecond roentgenogram of the head of a cat showing views before, during, and after the shot. A cavity similar to that in the dog's head is apparent in the microsecond roentgenogram of the cat.

The explosive effect of a high-velocity missile within the cranium increases with increased energy. With very high velocities, there is complete shattering of the skull, usually along suture lines. This effect is illustrated in figure 93. Movement of brain tissue during expansion of the temporary cavity pushes the bone apart.

To demonstrate the necessity of a liquid medium for the development of these pressure effects, the brain of a cat was removed through the foramen magnum and the air-filled head was then shot with a $\frac{1}{8}$-inch steel sphere moving 3,800 feet per second. A photograph of the cleaned skull of this cat is reproduced in figure 94. It will be noted that no shattering has occurred, the only damage being rather neat entrance and exit holes. Without a liquid medium, the high pressure necessary to blow skull bones apart cannot be built up.

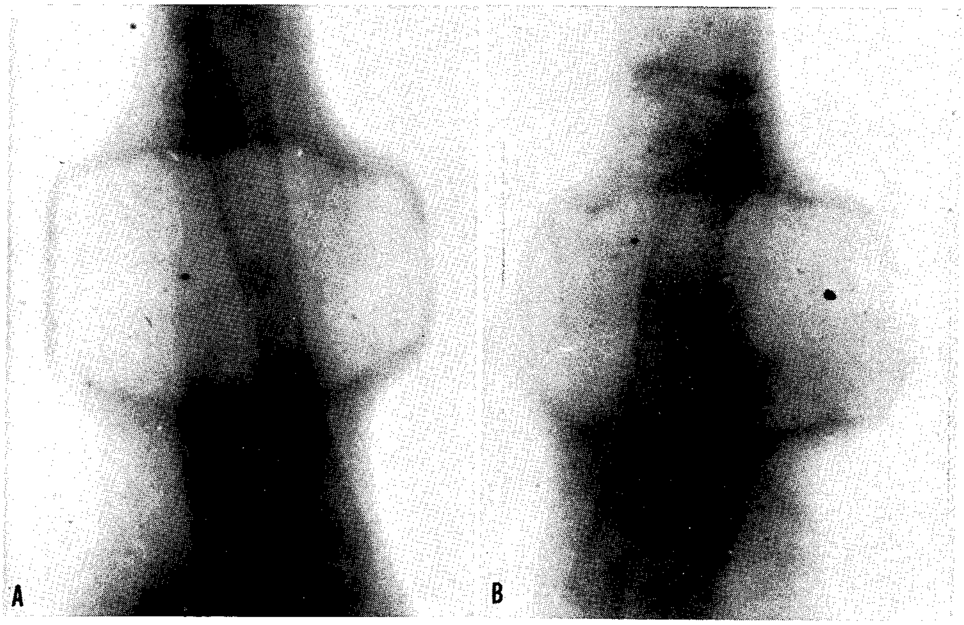


FIGURE 83.—Microsecond roentgenograms of thigh of a cat. A. Roentgenogram (No. 261) shows temporary cavity formed by a 4/32-inch steel sphere whose impact velocity was approximately 3,000 f.p.s. The energy lost by this sphere was approximately equal to that lost by the 8/32-inch sphere as shown in B. Note the similarity of the two cavities. B. Roentgenogram (No. 262) shows the temporary cavity formed by the passage of an 8/32-inch steel sphere whose impact velocity was approximately 1,500 f.p.s. Compare with A.

MOVEMENTS FOLLOWING COLLAPSE OF THE EXPLOSIVE CAVITY

In the preceding pages, the explosive cavity in soft tissue, with its volume many times greater than the volume of material swept out by the missile, was clearly demonstrated. It was reasonable to suppose that when the cavity collapsed such violent motion would not immediately stop. Investigation of the movement in soft tissue after the cavity has collapsed bears out this conjecture. The motion continues for a considerable length of time, long after the missile has passed by. Once again, it is instructive to examine the action in water and gelatin gel before proceeding to animals.

In water, the collapsing cavity closes in, entrapping the air that rushes in after the bullet. When the cavity is compressed to its minimum volume, it springs open again and the process is repeated. The cavity thus undergoes a series of pulsations. For a 1/8-inch steel sphere traveling with an impact velocity of 3,000 f.p.s., the first few pulsations have a period of about 8 milliseconds. The period is greatest for the spheres of greater energy. The period in seconds for all spheres was found to equal the product of 9.85×10^{-6} and the cube root

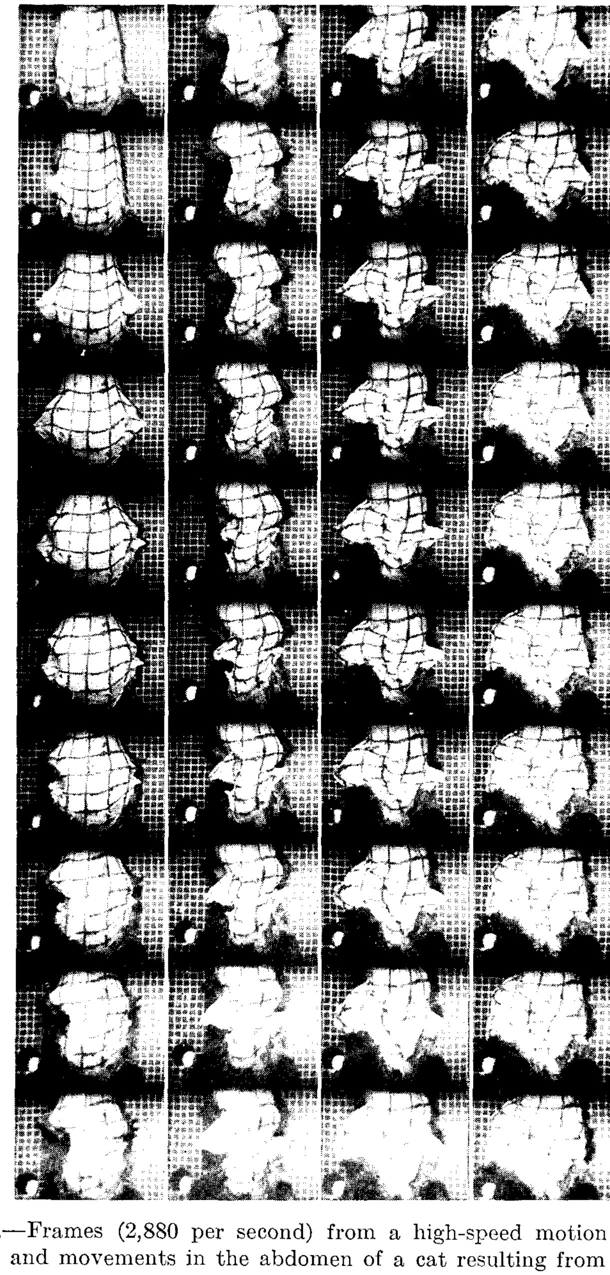


FIGURE 84.—Frames (2,880 per second) from a high-speed motion picture showing volume changes and movements in the abdomen of a cat resulting from the passage of a 5/32-inch steel sphere whose impact velocity was 3,800 f.p.s. The squares painted on the shaved abdomen are 1 inch apart. (Experiment No. 1, of 20 Nov. 1945.)

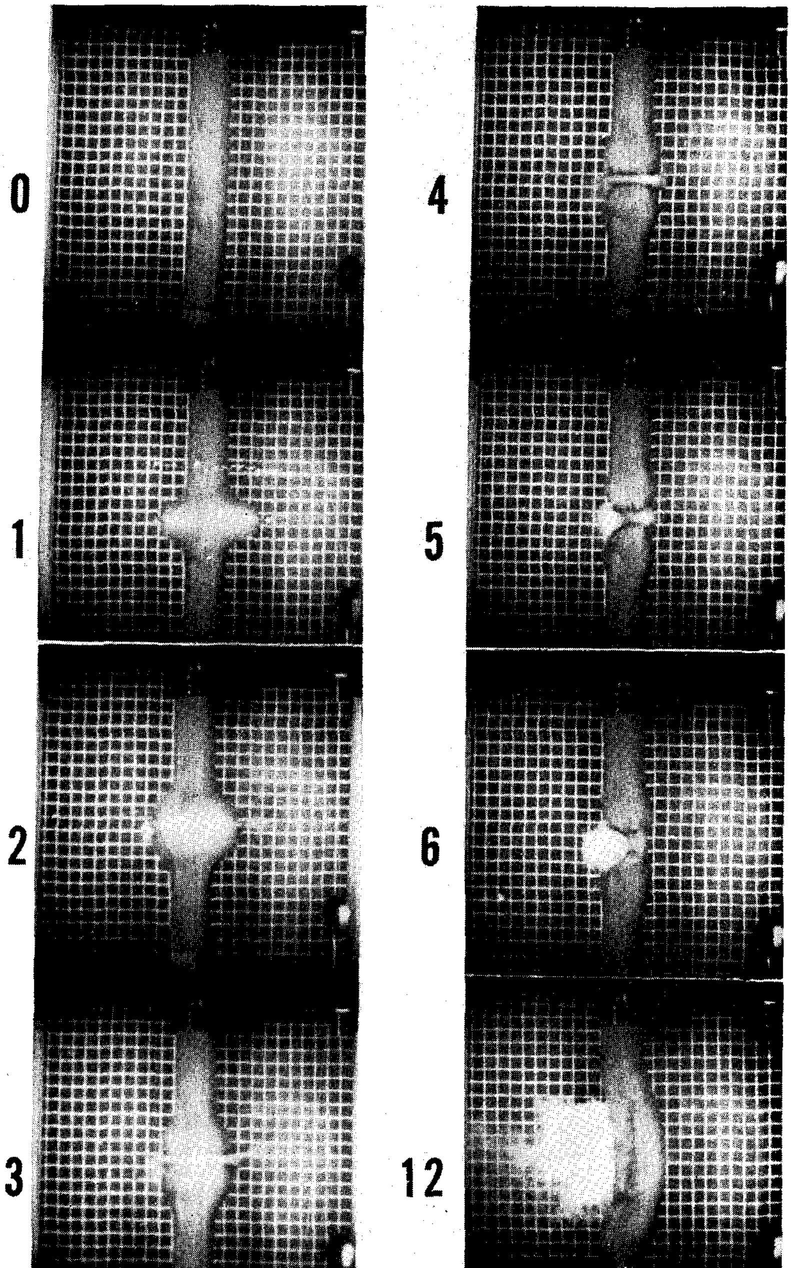


FIGURE 85.—Frames (about 2,400 per second) from a high-speed motion picture showing volume changes in a rubber tube filled with water, resulting from the passage of a small high-velocity steel sphere. Note the similarity in behavior to that of the abdomen shown in figure 84.

FIGURE 86.—Microsecond roentgenogram (No. 183) of the temporary cavity formed in the abdomen of a cat after the passage of $\frac{4}{32}$-inch steel sphere with an impact velocity of 3,200 f.p.s. Cavity age 400 microseconds.

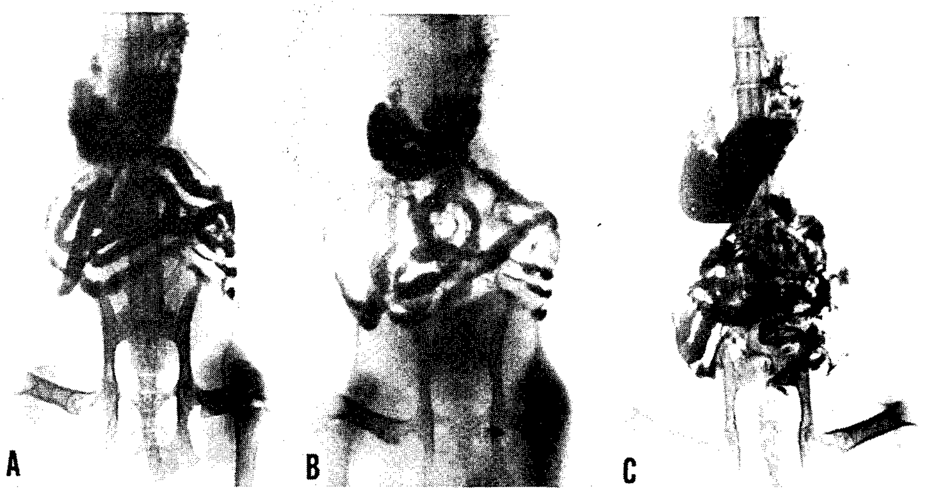


FIGURE 87.—Roentgenograms of abdomen of a cat. The alimentary tract has been made radiopaque with barium sulfate. A. Roentgenogram (No. 186) made before the shot. B. Microsecond roentgenogram (No. 186) showing the large temporary cavity formed after the passage of a $\frac{4}{32}$-inch steel sphere with an impact velocity of 3,200 feet per second. C. Roentgenogram (No. 186) made immediately after the shot. Note distribution of opaque material as compared with that shown in A.

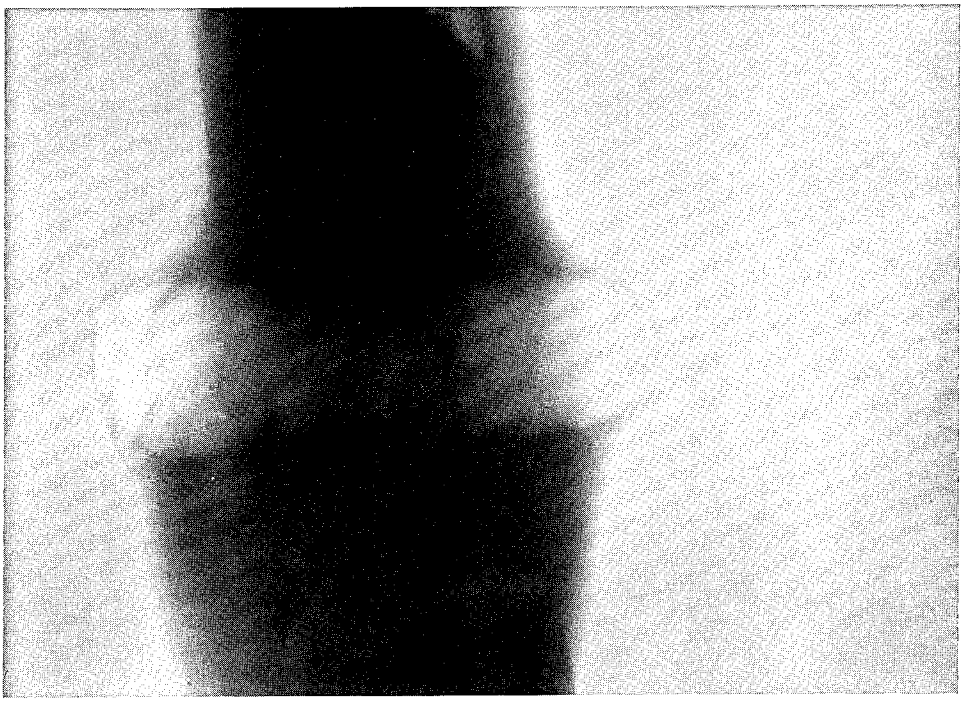


FIGURE 88.—Microsecond roentgenogram (No. 267) of the abdomen of a cat showing the temporary cavity formed by the passage of a small cylinder of steel (11 × 2.5 mm.) weighing 420 mg. Its striking velocity was 3,000 f.p.s. Note the irregular shape of the cavity.

of the impact energy in ergs. The periodicity of the cavity is clearly illustrated in figure 62, the first minimum appearing in frame 23 and the second in frame 47. The pulsations in water for a $\frac{6}{32}$-inch sphere traveling with a velocity of 3,000 f.p.s. have been observed to last at least one twenty-fifth of a second. The pulsations in water occur because air is trapped within the missile track. As air rushes into the cavity, the cavity is sealed off by Bernouilli forces.

In gelatin gel, the cavity also appears to pulsate about an air bubble, but in this case the pulsations are directed along the track of the missile. A typical pulsation cavity is shown in figure 95. The cavity closes in from the top and bottom to form two internal nipples, as can be seen in frame 11. Eventually the cavity breaks up in two segments, as shown in frame 22 (see also fig. 55).

When missiles pass through soft structures, such as the abdomen of a cat, violent motion of the tissues occurs. The larger the energy of the shot, the greater the action on the abdomen. Some concept of the violence of this movement can be obtained from inspection of figure 84. In frames 10 and 13 of figure 84, the abdomen is considerably indented where the bullet perforated. This is also shown in figure 96. Some of the expansive movement is directly upward toward the thoracic cavity. However, the motion in the abdomen is

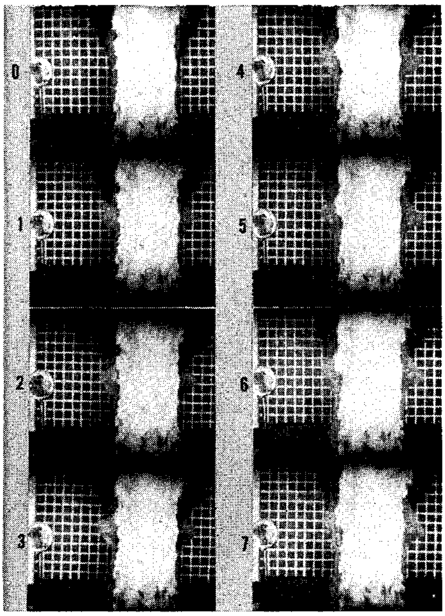


FIGURE 89.—Frames from a high-speed motion picture of the thorax of a cat, traversed by a 4/32-inch steel sphere with an impact velocity of 3,200 f.p.s. Compare with figure 84 and note the absence of pronounced movements and volume changes in the thorax.

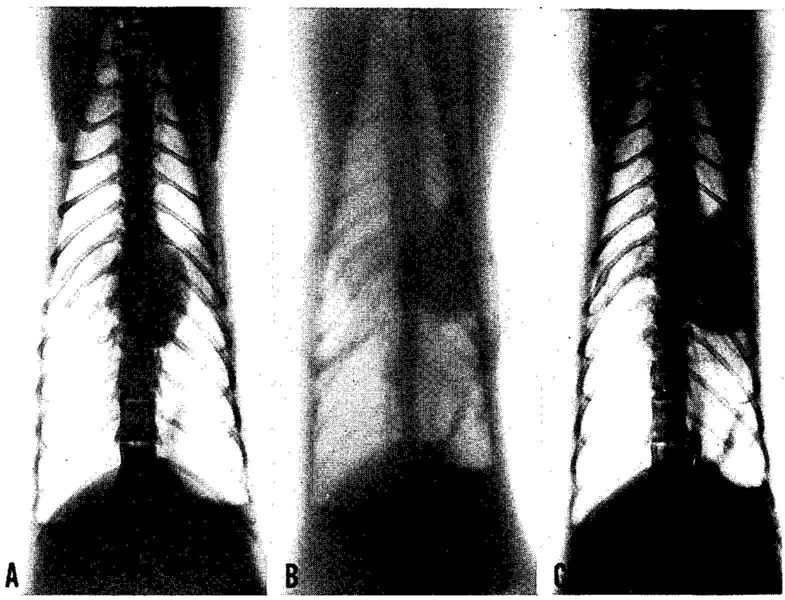


FIGURE 90.—Roentgenograms of the thorax of a cat. A. Roentgenogram (No. 189) taken immediately before the shot. B. Microsecond roentgenogram (No. 189) made 370 microseconds after the thorax was struck by a 4/32-inch steel sphere whose impact velocity was 3,200 f.p.s. Note that the temporary cavity does not show up well in the thorax. C. Roentgenogram (No. 189) made immediately after the shot. Note the manner in which the heart is displaced, although the missile did not strike the heart.

FIGURE 91.—Microsecond roentgenogram of the head of an anesthetized dog, showing a large temporary cavity within the cranium produced by the passage of a ⅛-inch steel sphere. At impact with the head, the sphere had a velocity of approximately 4,000 f.p.s. Entrance of the sphere was at the left in the roentgenogram, exit at the right. (Experiment No. 248.)

not like that of the pulsating cavity in the water tank but rather like the distortion waves which are set up in a block of gel when it is given a sharp blow. The microsecond roentgenograms show a complete absence of an oscillation bubble, as was seen in water.

The shot into the thigh of a cat also produces a violent action. The high-speed motion picture frames in figure 76, showing a cat leg, reveal this. When the leg is skinned, waves resembling waves on a water surface are produced, as in the "bullet-view" moving pictures of figures 97 and 98. These waves travel down the thigh with velocities ranging from 4.1 to 5.2 meters per second. It is not clear whether this wave was the regular muscular contraction wave (velocity between 6 and 12 meters per second) or rather a mechanical disturbance.

Unlike the abdomen, the cavity in the thigh pulsates on a partially air filled cavity. When the moving pictures are studied, these pulsations can be observed and timed. For example, a sphere traveling with a velocity of about 3,000 f.p.s. was observed to start pulsations having a period of about 3 milliseconds. Microsecond roentgenograms show an air bubble in the thigh at a late stage. Figure 99B is a microsecond roentgenogram taken 3.5 milliseconds after the missile passed through the leg. This is at a time when the second expansion of the cavity occurs and the entrapped bubble of air is plainly visible.

It is of interest to conjecture on what would happen to parts of the body when struck by a missile, if these parts were not confined by such structures as

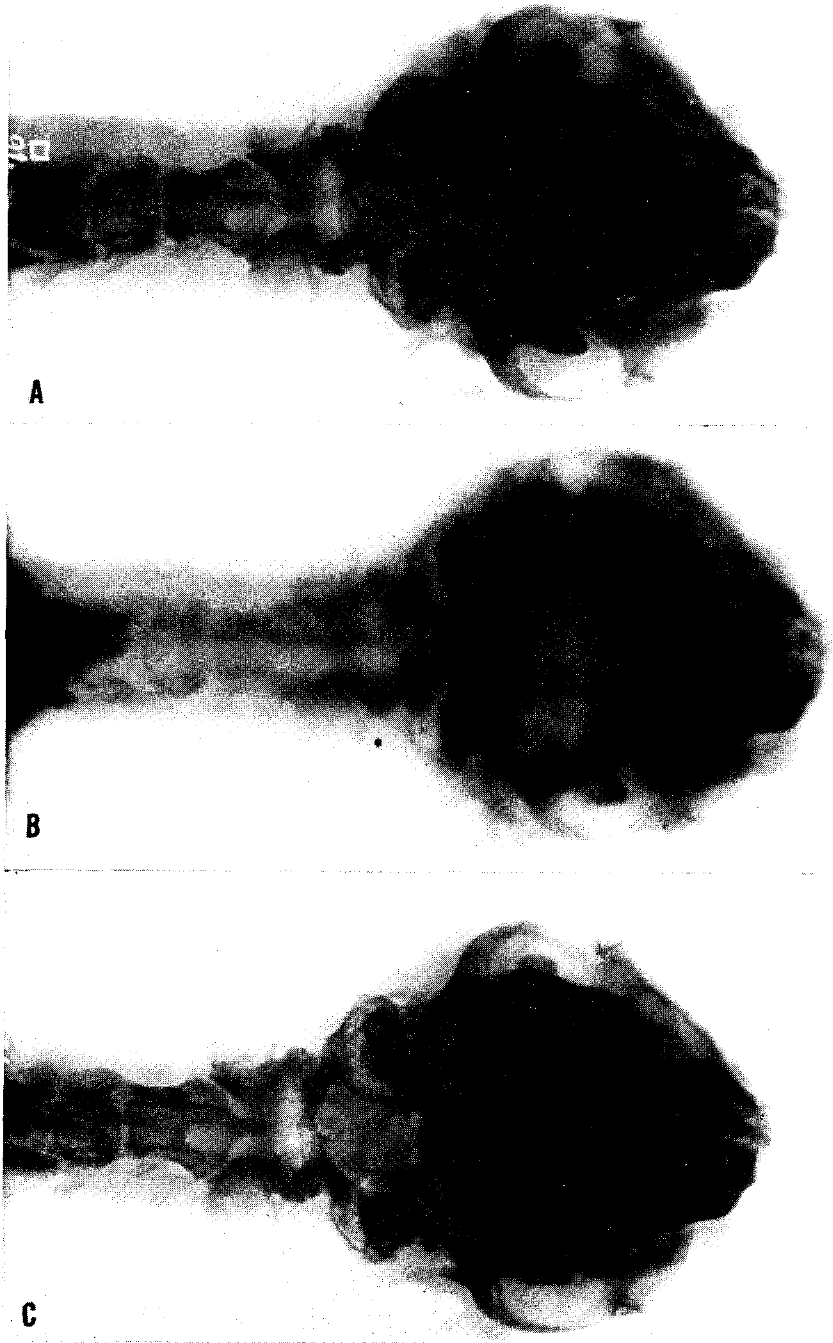


FIGURE 92.—Roentgenograms of the head of a cat. A. Roentgenogram (No. 76) made before the shot. B. Microsecond roentgenogram (No. 76) shows an early cavity. The ⅛-inch sphere struck with a velocity of 3,800 f.p.s. C. Roentgenogram (No. 76) made after the shot.

FIGURE 93.—Skull from head of cat struck in right temporal region by a ⅛-inch steel sphere with an impact velocity of approximately 3,800 feet per second. (Experiment No. 240.)

skin, abdominal wall, or skull. The disintegration of the tissue will presumably be greater when it is unconfined. In figure 100 is shown the bare muscles of the thigh as they are struck by a missile. The muscles are extensively separated, and the bullet hole shows clearly, although the path of the bullet was in the plane of the picture. In figure 101 is shown a pig spleen when struck by a missile. This picture was taken with two mirrors; the one above provides a top view, while the one on the left shows the entrance hole. The tissue flies apart in all directions.

NATURE AND EXTENT OF DAMAGE AROUND THE WOUND TRACK

The chief emphasis in this section will be on wounds of the thigh. Some attention, however, will be given to wounds of the abdomen and thorax. The nature of the damage produced in the thighs of anesthetized dogs and cats by high-velocity missiles is representative of that occurring in muscular and connective tissues. In consideration of such a wound, it is necessary to distin-

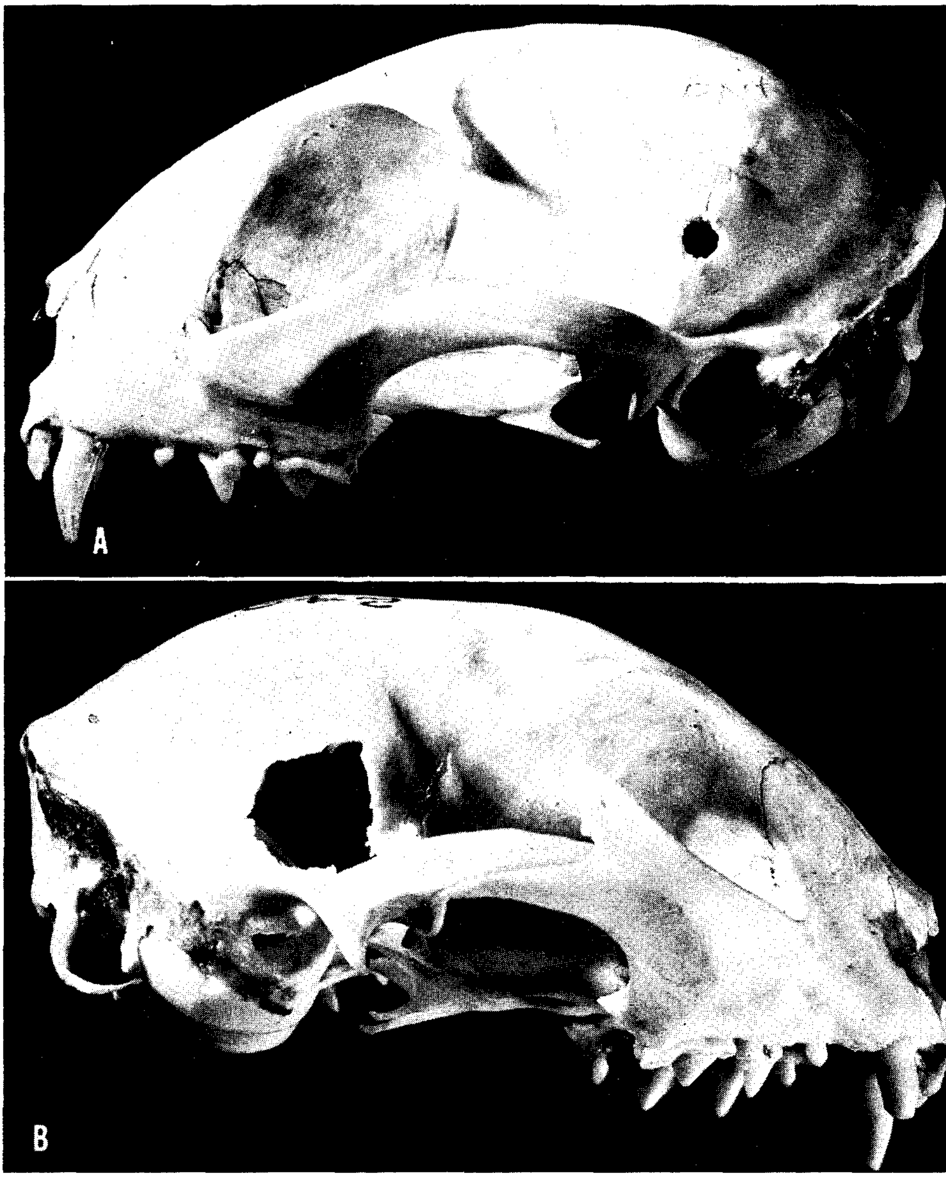


FIGURE 94.—Photographs of the skull of a cat, showing entrance and exit holes produced by a ⅛-inch steel sphere with an impact velocity of 3,800 f.p.s. Head of cat severed from body and brain removed before the shooting. A. Entrance site in left temporal region. B. Exit site in right temporal region.

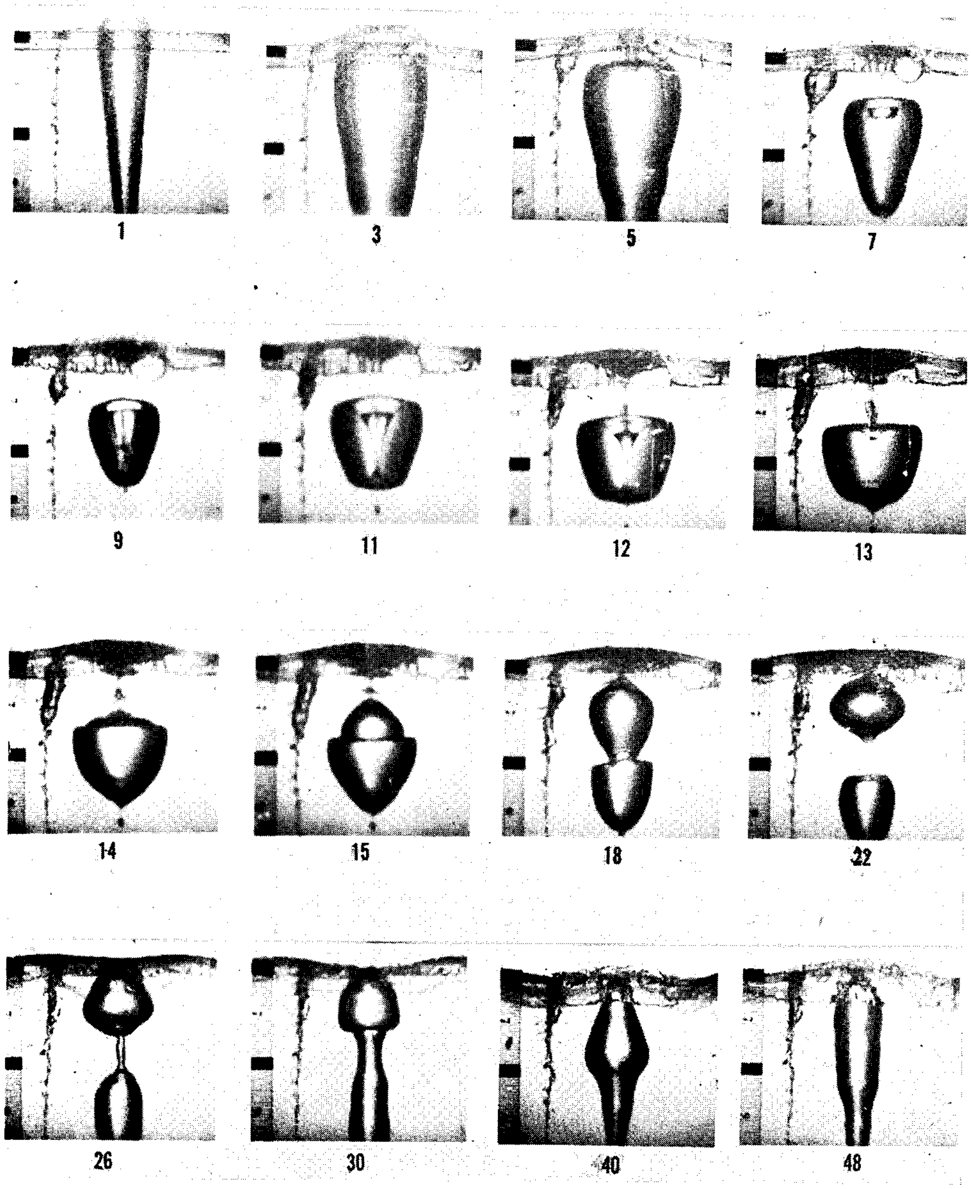


FIGURE 95.—Frames (1,920 per second) from a motion picture (No. 147) of the cavity in gelatin produced by a $\frac{5}{32}$-inch steel sphere with impact velocity of about 3,000 f.p.s. The distance between two black marks on left is 5 cm. In frames 7 to 11, the top and the bottom of the cavity are moving toward each other producing internal nipples which later (frame 15) separate again. The single cavity breaks into two cavities (frame 22) which again join and slowly collapse to produce a permanent missile track, similar to the one which can be seen on the left.

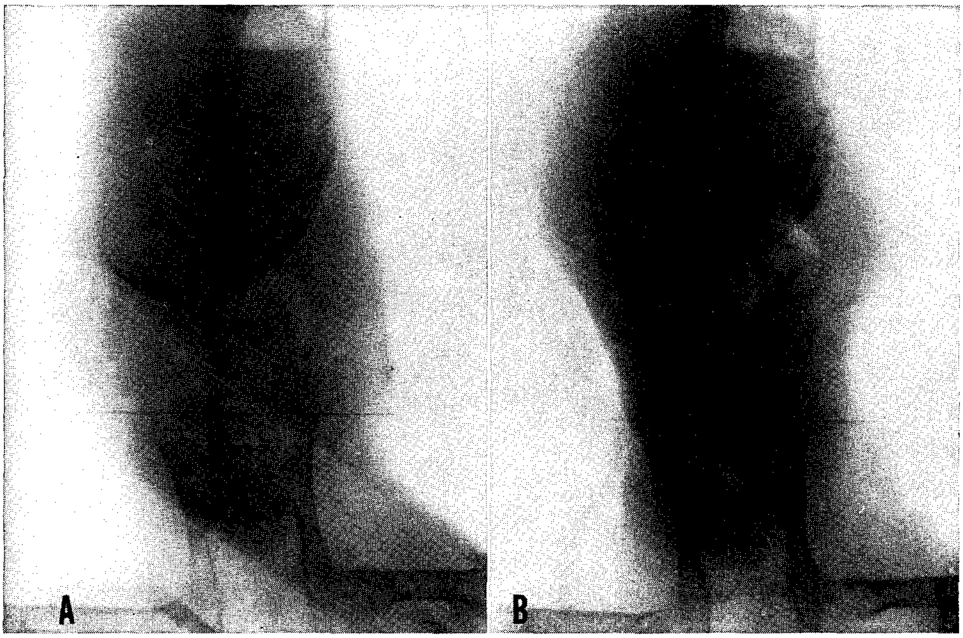


Figure 96.—Microsecond roentgenograms of abdomen of a cat. A. Roentgenogram (No. 463) shows barium sulfate in stomach. B. Roentgenogram (No. 464) taken 5.5 milliseconds after a 5/32-inch steel sphere (impact velocity 3,800 f.p.s.) passed through at the level of the narrow line. The time corresponds to the collapse of the temporary cavity. Note that the abdomen is still enlarged at the stomach level and narrow at the missile level but that there is practically no cavity within; the collapse is complete.

guish between damage to soft tissues, such as muscle and connective tissues, and damage to the more specialized structures of the thigh, such as the femur, nerves, and larger blood vessels. Only those in the first category will be described here, while damage to the more specialized structures will be considered later (pp. 200–211).

Figure 97.—Frames (2,280 per second) from a motion picture (No. 154) of the skinned leg of a cat struck by a 5/32-inch sphere moving with a velocity of about 2,000 f.p.s. The right side of each frame shows the entrance hole and subsequent changes as the sphere strikes head on; the left side is the reflection in a mirror viewed perpendicular to the missile path. Note that the entrance hole in frame 1 is obscured by spray in the next three frames. A definite bulge appears on the profile of the right hand picture in frame 7 and travels down the muscle like a wave (velocity 4–5 meters per second), passing out of view about frame 19.

Figure 98.—Frames (2,160 per second) from a motion picture (No. 153) of a skinned cat thigh struck by a 5/32-inch steel sphere (0.3 gram) traveling with a velocity of about 3,000 f.p.s. The right side of each frame shows the entrance hole and subsequent changes as the sphere strikes head on; the left side is a reflection in a mirror viewed at right angles to the bullet path. Note in frame 2 that the explosive cavity produces a bulge on the side of the thigh. The gyrations of the entrance hole are clearly shown in frames 1, 2, and 3.

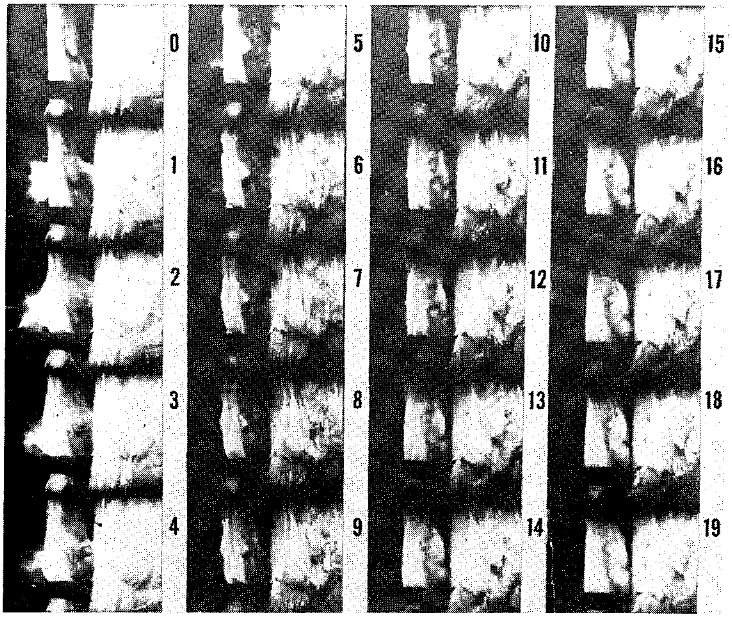


FIGURE 97. (*See opposite page for legend.*)

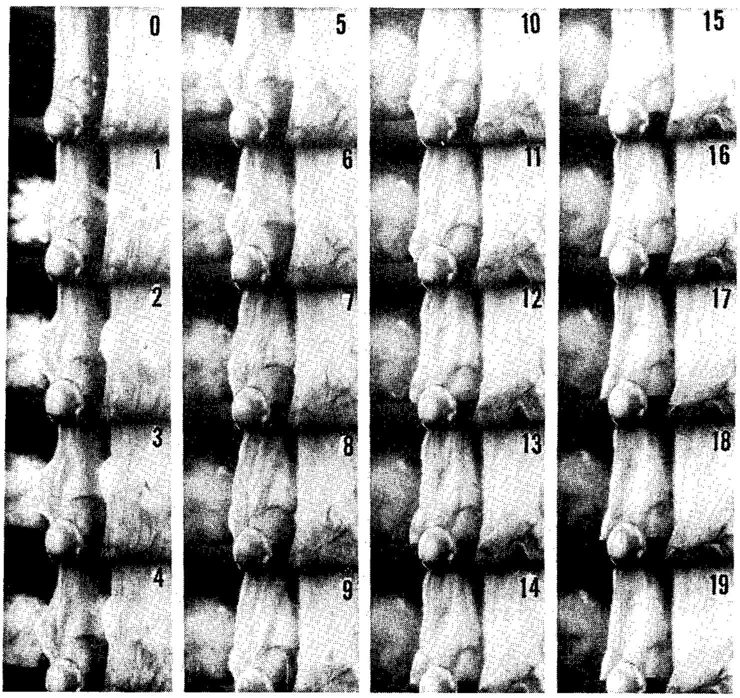


FIGURE 98. (*See opposite page for legend.*)

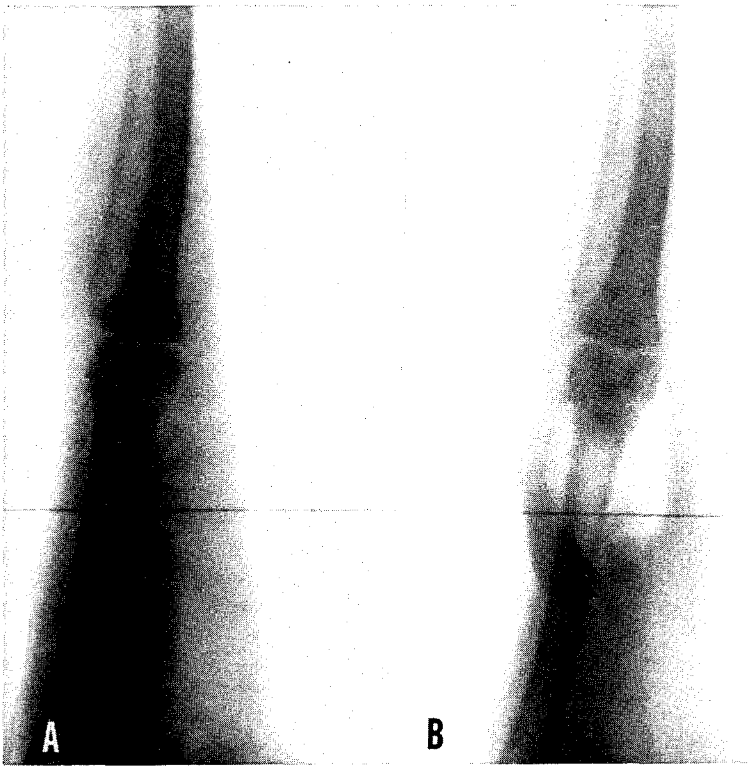


FIGURE 99.—Microsecond roentgenograms of the thigh of a cat. A. Roentgenogram before a shot. B. Roentgenogram (No. 474) taken 3.5 milliseconds after a ⅛-inch steel sphere with an impact velocity of 3,000 f.p.s. has perforated the thigh. The entrapped air bubble causes the thigh to pulsate a few times.

Obviously, soft tissues directly in the path of a missile are badly damaged. These tissues are reduced to a pulp and much of the material is actually thrown out of the thigh during the expansion of the temporary cavity, as discussed previously (pp. 167–180). The loss of this material leaves an excavation, the permanent cavity.

It has been shown earlier that the expansion of the temporary cavity results in a stretching and tearing of the tissues for a considerable distance away from the missile track. With the collapse of the temporary cavity, these tissues regain their original positions and, except for darkened areas of extravasated blood, may have a fairly normal appearance, macroscopically.

A more complete assessment of the exact type of damage suffered by these soft tissues can be had from a histologic study. In each case to be described, a considerable volume of tissue adjacent to the wound cavity was fixed and sectioned at thicknesses ranging from 20 to 50 microns.

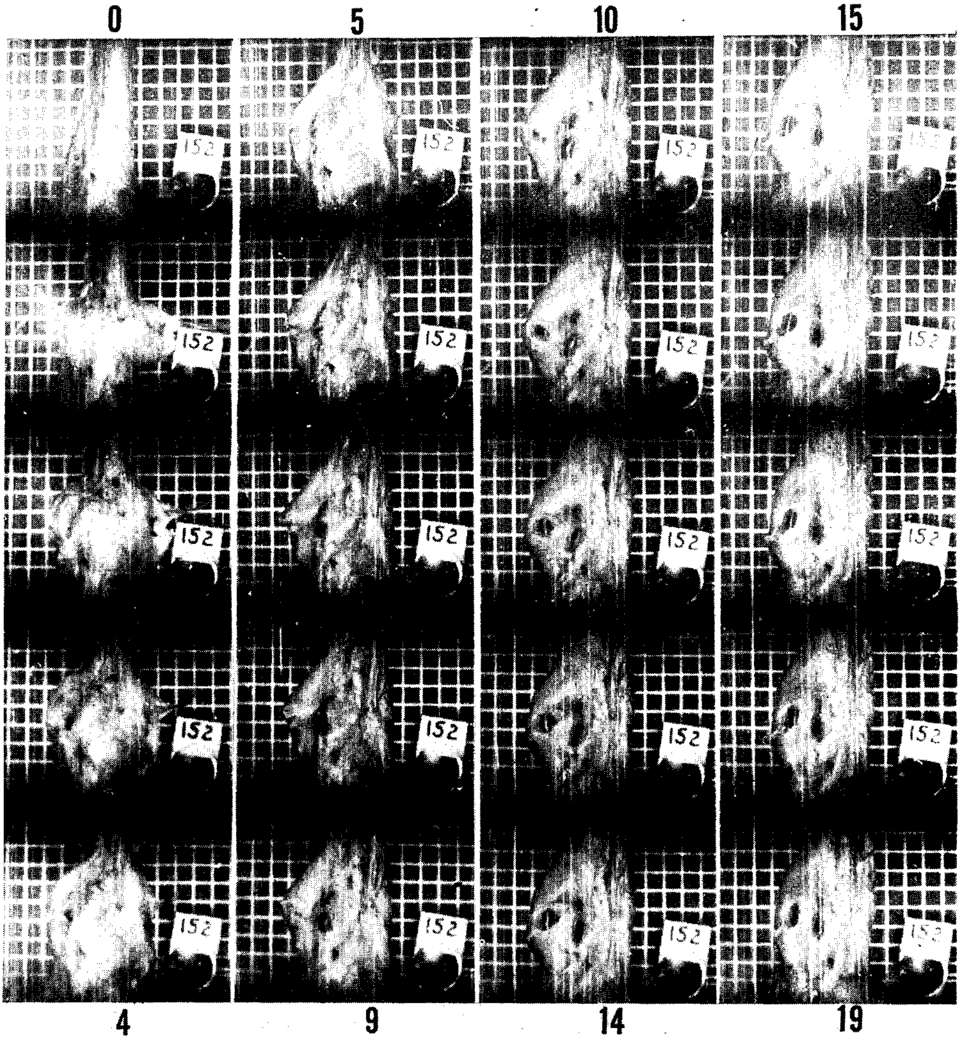


FIGURE 100.—Frames from a high-speed motion picture (No. 152) of the muscles of the thigh of a cat blown apart by a ⅛-inch steel sphere traveling with a velocity of about 3,000 f.p.s. The sphere is passing from left to right. Note how the muscle which is first struck by the missile swings out at right angle to the missile path so that the entrance hole is clearly visible.

Tissues bordering the wound cavity in the thigh suffer two primary types of damage: (1) That affecting the muscle fibers and (2) that affecting the intermuscular and intramuscular connective tissues and small blood vessels. Damage to the muscle fibers is manifested by a coagulation and swelling of the fibers

FIGURE 101.—Frames (1,800 per second) from a motion picture (No. 20, 26 May 1944) of a ⅛-inch steel sphere (striking velocity 3,000 f.p.s.) passing through a pig spleen. The squares on background are centimeters. A mirror above shows the top view and one to the left shows the entrance view. Note the marked splash of material at entrance and exit with complete disintegration of tissue.

in a region extending for some distance from the wound cavity. The muscle fibers (fig. 102) in this region are unique in their staining properties and often swell to twice the diameter of normal fibers. Swollen fibers are well shown by the photomicrograph in figure 102A. These fibers should be compared with normal undamaged fibers, photographed at the same magnification and shown in figure 102B. More distal to the wound cavity, "muscle clots" are formed, accompanied by other phenomena of cellular disorganization. Still further distally, however, the muscle fibers exhibit a remarkably small amount of damage despite the fact that they have been moved considerably by the expansion of the temporary cavity. The three regions just mentioned are visible in the photomicrograph in figure 102C. Normal undamaged fibers are seen at the left of the section, muscle clots in the central region, and swollen fibers to the right.

Vascular damage is extensive for a considerable distance from the permanent wound cavity. Multiple ruptures of the capillaries occur, and the muscle fibers are widely separated by accumulations of extravasated blood. This is illustrated by the photomicrograph in figure 103. These areas of hemorrhage may extend for considerable distances along fascial lines. Histologic sections show that the larger blood vessels, even though they lie close to the wound cavity, are undamaged. Bleeding around the wound appears to be a matter of capillary bleeding, unless a larger blood vessel is struck directly.

It should be emphasized that these observations are based on materials fixed within an hour or so after the shot. No attempt has been made to conduct survival studies or to follow the course of wound healing.

Because of their structural characteristics, it is very difficult to determine the exact type of damage suffered by the diffuse intermuscular connective tissues. They are elastic, and, as a result, the permanent cavity formed in them is quite small. Examination of areas around the wound shows that the individual muscles are often widely separated and stripped from their surrounding connective tissues. It appears quite likely that a great deal of the expansion caused by a missile follows these intermuscular fascial planes and causes damage in these tissues at considerable distances from the wound cavity.

Because of the heterogeneous nature of the tissues and organs involved, wounds of the abdomen are much more difficult to evaluate accurately. If the missile passes through the intestinal mass, regions of the intestine directly in the path of the missile are usually completely severed or exhibit large tears. A chief factor in causing damage in the abdomen is the rapidly expanding temporary cavity which momentarily blows apart the components of the intestinal mass, as illustrated by high-speed motion pictures and microsecond roentgenograms on pages 182 through 185. This cavity may produce large tears in the mesenteries with damage to such organs as the pancreas and spleen. Breaks in many of the mesenteric blood vessels occur, causing severe hemorrhage into the peritoneal cavity.

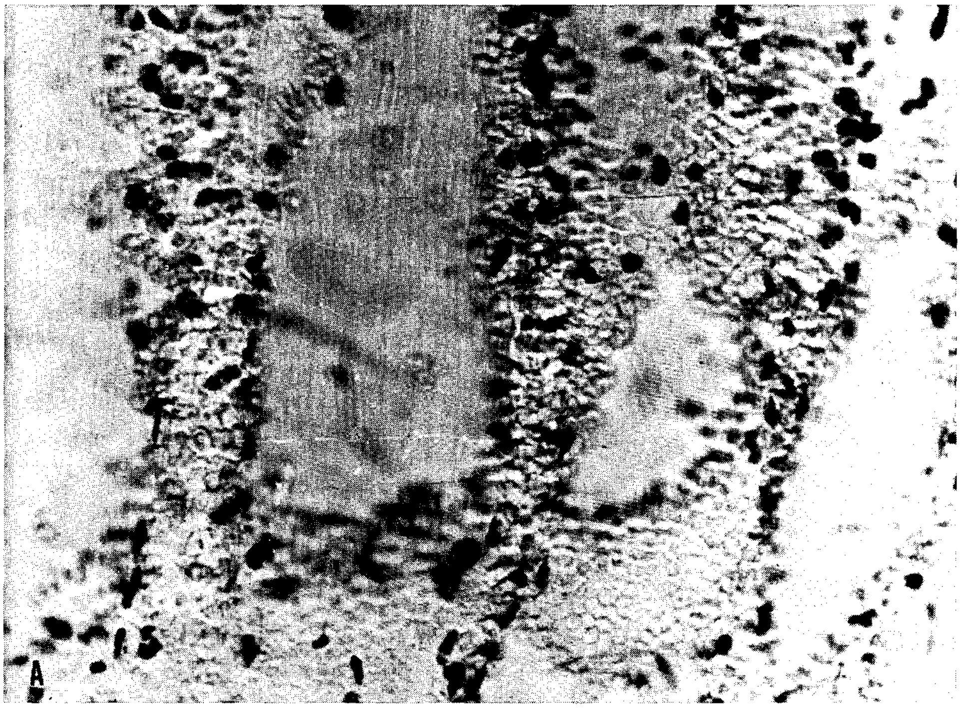
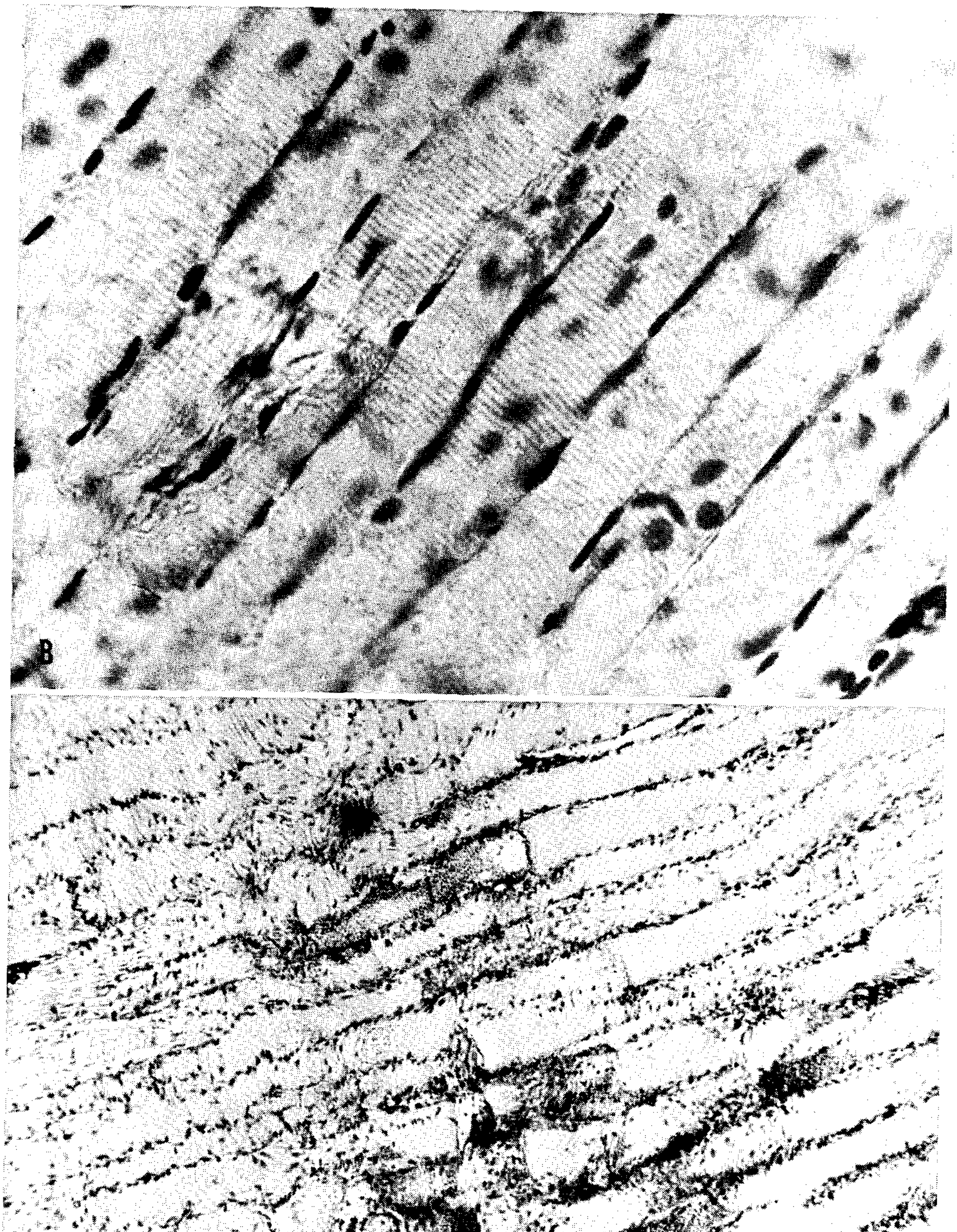


FIGURE 102.—Photomicrographs showing damaged and undamaged muscle fibers adjacent to the wound cavity in the thigh of a dog, produced by a $\frac{4}{32}$-inch steel sphere with an impact velocity of 3,035 feet per second. A. Photomicrograph showing damaged muscle fibers. Compare with uninjured muscle in B and note that the muscle fibers are approximately two times the diameter of normal muscle fibers. Note the large amount of extravasated blood between the fibers. B. Photomicrograph showing apparently undamaged muscle at a distance from the wound cavity. Compare with the damaged muscle in A. C. Photomicrograph of section of muscle adjacent to the wound cavity. Undamaged regions of the fibers are shown at the left, areas with "muscle clots" in the center, and badly swollen portions of the fibers to the right.

Perforations of the intestine are often observed at points quite distant from the path of the missile. These are undoubtedly due to rapid pressure changes associated with the temporary cavity, acting on gas contained in the intestine. A short period of lowered pressure in the cavity around the intestine causes the intestine to explode at points where these gas pockets are present, as explained on pages 211–223.

Damage to thoracic structures was restricted primarily to lung tissue, as in none of the experiments were the heart or great vessels struck directly. The wound track in lung tissue was never large, probably because of the sponginess and elasticity of this type of tissue. The thorax, on autopsy, usually contained a considerable amount of blood, a result of hemorrhages of the smaller


B
C

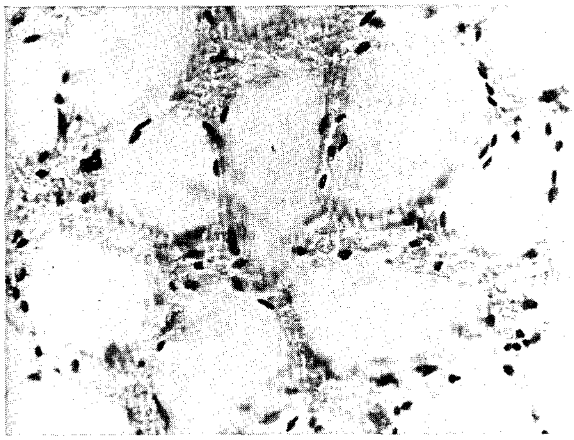


FIGURE 103.—Photomicrograph showing swollen muscle fibers of a dog's thigh in cross section. Note the large amount of extravasated blood between the fibers.

pulmonary vessels. In all the animals studied, the lungs were greatly collapsed, much more so than is usually observed after pneumothorax (pp. 171–180).

DAMAGE TO BONE BY HIGH-VELOCITY MISSILES

Damage to bone can be discussed under two headings: (1) Damage to the long bones, particularly the femur and humerus; and (2) damage to flat bones, such as those which comprise the skull.

The most obvious type of fracture of a long bone is one which results from a missile striking the bone directly. In none of the experiments was a deliberate attempt made to strike either the femur or the humerus. However, an occasional stray shot did hit the bone, and a number of microsecond roentgenograms were obtained of thighs in which this was the case.

Figure 104 is a microsecond roentgenogram of the thigh of a cat, made immediately after the passage of a $\frac{4}{32}$-inch steel sphere whose impact velocity was 3,000 f.p.s. The sphere struck the femur directly. The fact that the bone has been hit has not markedly affected the expansion of the temporary cavity. In fact, it appears from this roentgenogram that the femur also "explodes," in a manner very similar to the soft tissues around it.

A second case is shown in the microsecond roentgenogram in figure 105 where the femur was struck by a small fragment (originally part of a 75 mm. shell). In this case, the fragment was broken into two pieces as a result of its impact with the bone. One piece has remained in the thigh, the second has emerged. Figure 106 is a microsecond roentgenogram of a beef rib, made immediately after the passage of an $\frac{3}{32}$-inch steel sphere whose impact velocity was 2,800 f.p.s. The behavior of the bone is very remindful of the manner of formation of the temporary cavity in soft tissues.

The question whether bone fragments may be driven out into the soft tissues and act as secondary missiles is a significant one. The present observa-

FIGURE 104.—Microsecond roentgenogram (No. 11) of the thigh of a cat made immediately after the passage of a 4/32-inch steel sphere with an impact velocity of 3,000 f.p.s. The sphere struck the femur directly. Note the "explosive" behavior of the femur.

tions indicate that fragments fly out into the temporary cavity and, with the collapse of the cavity, are forced back to approximately their former position. Dissection of wounds, where such extensive shattering of a bone has occurred, rarely discloses fragments at any distance from the bone. This finding is supported by the roentgenogram of a cat thigh, shown in figure 107, which was made shortly after the femur was struck by a 4/32-inch steel sphere whose impact velocity was 3,000 f.p.s. The sphere was fired parallel to the X-ray beam so as to pass into the plane of the paper. Although the bone is badly shattered, the fragments are closely clumped together and seem to retain a connection with the parent bone, possibly being held there by the fibrous periosteum. They are free to move but actually are not separated from the bone.[16]

A second and less severe type of fracture is that produced by a missile which passes near but does not strike the bone directly. This can be termed an indirect fracture. Roentgenograms of a large number of thighs show that the femur can be broken even though the missile passed as far as 2 or 3 centimeters from the bone. A roentgenogram of this type of fracture is shown in figure 69. The wound cavity appears as a light area to the right of the femur.

[16] The wounds of battle casualties frequently contain bone fragments along the course of the permanent wound track. This is especially true in penetrating wounds of the head where small bone fragments derived from the skull are commonly found in the permanent wound track in the brain. In penetrating wounds of the thorax where there have been fractures of the vertebras, ribs, or sternum, bone fragments are frequently embedded in lung tissue. In wounds of the extremities caused by high-velocity shell fragments, fragments of long bones are frequently embedded in the soft tissue adjacent to the permanent wound track. This does not indicate that bone fragments are important as secondary wounding agents, but it does show that bone fragments are not always retained in close approximation to the parent bone.—J. C. B.

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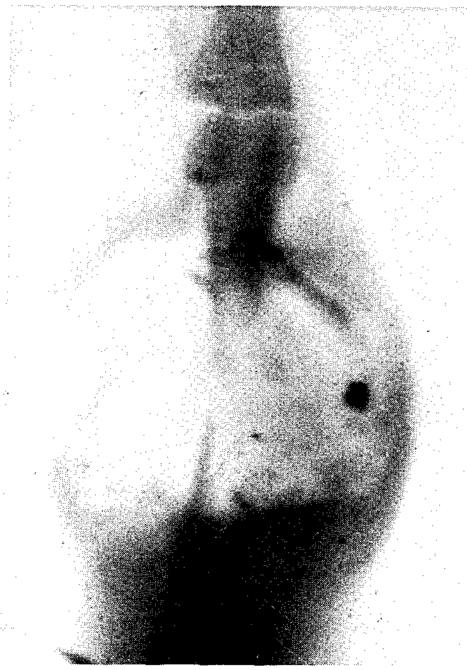

FIGURE 105.—Microsecond roentgenogram (No. 276) of the thigh of a cat made immediately after the passage of a fragment of a 75 mm. shell with an impact velocity of 3,000 f.p.s. The fragment broke into two pieces as a result of striking the bone. One piece has been retained in the thigh; the second has exited and does not show in the picture.

FIGURE 106.—Microsecond roentgenogram (No. 144) of a beef rib made immediately after the rib was struck by an $\frac{3}{32}$-inch steel sphere with an impact velocity of 2,800 f.p.s. Note the "explosive" nature of the fracture.

It is also clear that the cavity has expanded toward the femur and that the bone is fractured, as if it had received a heavy blow from the direction of the cavity.

Figure 108 is a roentgenogram of the thigh of a dog made after the thigh was struck by an $\frac{3}{32}$-inch steel sphere with an impact velocity of 4,000 f.p.s. The femur has been fractured although the sphere passed at a considerable distance from it.

A second case is illustrated by the roentgenogram shown in figure 109. In this case, the thigh was struck midway between the femur and the sciatic nerve. The nerve in this case has been made radiopaque by the injection of iodophenylundecylate. The femur shows a simple fracture. This type of fracture should be compared with the marked comminution of that shown in figure 107, which resulted from a direct hit on the bone (see also roentgenograms on pp. 173–181).

The incidence of the indirect type of fracture appears to be related to the

striking energy of the missile. In the case of $\frac{4}{32}$-inch steel spheres, it was found that no fractures of this type occurred at velocities ranging from 1,000 to 2,400 f.p.s. At 2,800 to 3,000 f.p.s., fractures were found in 20 percent of the cases and at the highest velocities used, 4,500 to 4,800 f.p.s., in 45 percent of all the cases.

It is significant that, of the total number of indirect fractures, 80 percent were of the femur and only 20 percent of the humerus. These data are based on 172 cats in which both forelimbs and hind limbs were shot. A probable explanation of this result is that the humerus is architecturally better able to stand the high pressures imposed on it by the missile than is the femur. Also, the humerus appears to be better protected by the surrounding muscle and fascia than is the femur.

The explanation of the indirect type of fracture is found in the rapidly expanding temporary cavity. As this cavity expands, high pressures are brought to bear against the rigid bone. The situation is similar to that of striking the bone a hard blow with a hammer. Figure 110 illustrates this point nicely. This figure shows a microsecond roentgenogram of the thigh of a cat made immediately after the passage of a $\frac{4}{32}$-inch steel sphere whose impact velocity was 2,800 f.p.s. The temporary cavity is expanding, and careful examination of the femur shows that a clean fracture line has appeared in the bone. A second and similar case is shown in figure 111.

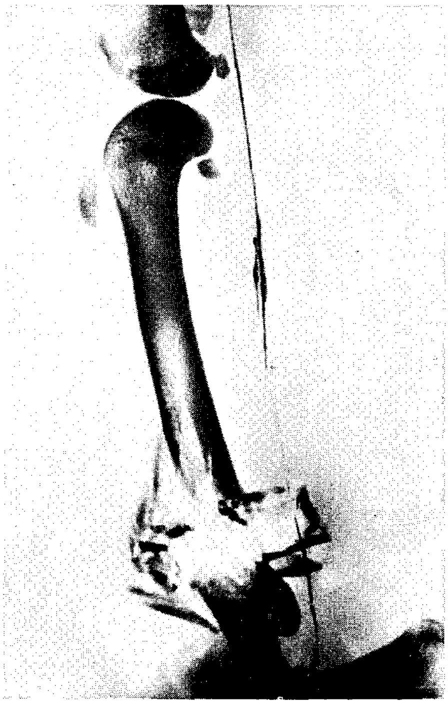

FIGURE 107.—Roentgenogram (No. 288) of the thigh of a cat made after the femur was struck by a $\frac{4}{32}$-inch steel sphere with an impact velocity of 3,000 f.p.s. Note the shattered femur and the manner in which the fragments are clustered around it. The sciatic nerve also shows in this figure as the dark line to the right of the femur.

FIGURE 108.—Roentgenogram (No. 108) of the thigh of a dog made after the thigh was struck by an 8/32-inch steel sphere with a velocity of 4,000 f.p.s. The femur has been shattered, although not struck directly by the sphere.

Studies on skull damage were made chiefly with 4/32-inch steel spheres. Damage to the skull varied from the presence of neat holes, at the points of entrance and exit, to extensive fractures, sometimes resulting in complete shattering of the skull into a large number of separate fragments. Splitting along suture lines was often a prominent type of damage.

The degree of skull damage was found to increase with missile velocity and probably depends on the striking energy of the spheres. This is illustrated by the series of skulls shown in figure 112. Figure 112A demonstrates the neat type of hole which ordinarily occurs when the skull is hit by a 4/32-inch steel sphere with an impact velocity of approximately 1,100 f.p.s. The more extensive damage which occurs at higher velocities is shown in figure 112B, a case where the skull was struck with a sphere having a velocity of approximately 4,000 f.p.s. The extensive splitting along sutures and shattering which frequently occurred at the higher velocities is illustrated in figure 112C, a skull struck with a sphere whose impact velocity was approximately 4,600 f.p.s. In most of these latter cases, the skull is completely shattered and must be recovered piece by piece.

Much of this extreme damage to the skull undoubtedly results from pressure developed within the skull at the time a temporary cavity is formed in the brain immediately after passage of the missile. A complete account of the role of the temporary cavity in head wounding has already been presented (pp.177–180).

DAMAGE TO BLOOD VESSELS AND NERVES NEAR WOUND TRACK

It has been pointed out (pp. 189–200) that bleeding from a wound in the soft tissues of the thigh resulted primarily from the rupture of capillaries and small blood vessels. It has been a matter of frequent observation that the larger blood vessels, particularly the arteries, passing in or near the wound cavity were apparently undamaged. These vessels are very elastic, and the assumption was made that, unless they lay directly in the path of the missile, they were merely blown aside during the expansion of the temporary cavity and sprang back to their original positions with its collapse.

The correctness of this assumption is confirmed by microsecond X-ray studies (fig. 113). Figure 113A shows a roentgenogram of the thigh of a cat in which the femoral artery and its tributaries have been made radiopaque with barium sulfate. An attempt was made to fill the femoral vein, but too much blood remained in this vessel to give a complete injection. Figure 113B is a microsecond roentgenogram of the same thigh made immediately after the passage of a 4/32-inch steel sphere with a velocity of 3,200 f.p.s. The large temporary cavity, resulting from the passage of the missile, is seen in cross section. It is evident that, although the sphere passed at a considerable distance from the vessels, they have been forced aside and follow the contour of the margin of the cavity. Figure 113C shows the same thigh immediately

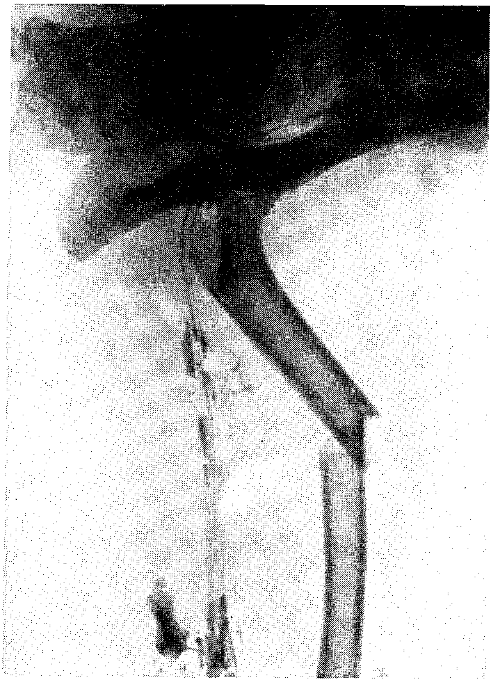

FIGURE 109.—Roentgenogram (No. 229) of the thigh of a cat made after the passage of a 4/32-inch steel sphere with a velocity of 3,000 f.p.s. Note that the femur has been fractured, although not struck directly by the missile. The sciatic nerve to the left has been injected with iodophenylundecylate. Compare with figure 107.

FIGURE 110.—Microsecond roentgenogram (No. 135) of the thigh of a cat showing the temporary cavity formed after the passage of a $\frac{4}{32}$-inch steel sphere whose impact velocity was 2,800 f.p.s. Note the fracture line appearing in the femur.

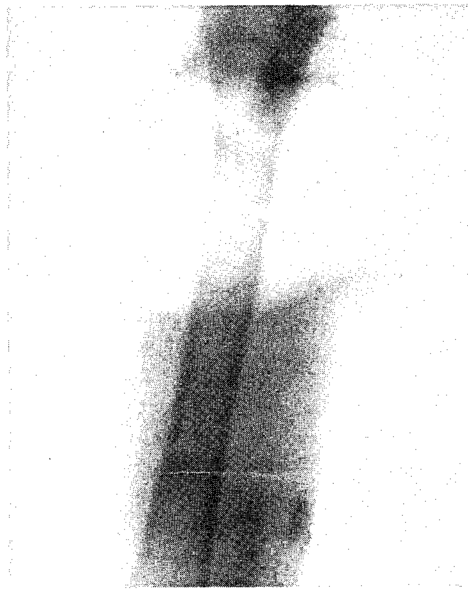

FIGURE 111.—Microsecond roentgenogram (No. 276) of the thigh of a cat showing the temporary cavity formed after the passage of a small steel fragment. Note fracture line in the femur.

after the shot. The location of the permanent cavity is well defined. The blood vessels have moved back to their original position as shown in figure 113A. Subsequent dissection disclosed that both the artery and the vein were undamaged. The magnitude of the blow suffered by these vessels was such as to fracture the femur.

Unlike arteries and veins, large nerves, as the sciatic nerve of the cat, are often severely damaged as a result of being displaced by the temporary cavity. This displacement may cause a stretching and a compression of the nerve sufficient to block its ability to conduct impulses, even though there is no detectable break in the continuity of the nerve.

The sciatic nerve can be made radiopaque by injecting it with either iodobenzene or iodophenylundecylate (fig. 114). The exact manner in which these substances follow the nerve is not well understood and, in many cases, only a single small channel in the rather broad nerve is outlined.

Microsecond roentgenograms show that the nerve is greatly displaced as the temporary cavity expands. Figure 114C is a microsecond roentgenogram of the thigh shown in figure 114B, made immediately after the passage of a $\frac{4}{32}$-inch steel sphere with a velocity of 3,200 f.p.s. The cavity is seen in cross section. The roentgenogram shows that the nerve has been pushed aside

FIGURE 112.—Photographs of cat skulls. A. Neat type of hole formed by the passage of a $\frac{5}{32}$-inch steel sphere with an impact velocity of 1,100 feet per second. B. More extensive damage to the skull produced by a $\frac{5}{32}$-inch steel sphere which struck with a velocity of 4,000 feet per second. Note the extensive splitting along suture lines. C. Extreme damage produced by a $\frac{5}{32}$-inch steel sphere which struck with a velocity of 4,600 feet per second.

and follows around the margin of the cavity. Because of the extreme rapidity with which this displacement occurs, the situation is comparable to striking the nerve a sharp blow. Figure 114D shows this same nerve immediately after the shot. Subsequent dissection showed no break in the continuity of the nerve and nothing to suggest gross anatomic damage to the nerve.

In a number of cases where the nerve had been subjected to compression and stretching by the expansion of the temporary cavity, conduction, as determined by electrical stimulation, was blocked. In general, it was necessary for the missile to pass within 1 centimeter of the nerve in order to block conduction. Nerves at a greater distance showed normal conduction.

Nerves in which conduction was blocked as a result of a "near miss" showed no externally detectable break in continuity. However, histologic examination of the nerves showed structural changes which accounted for the loss of conduction. Figure 115 is a photomicrograph of a longitudinal section

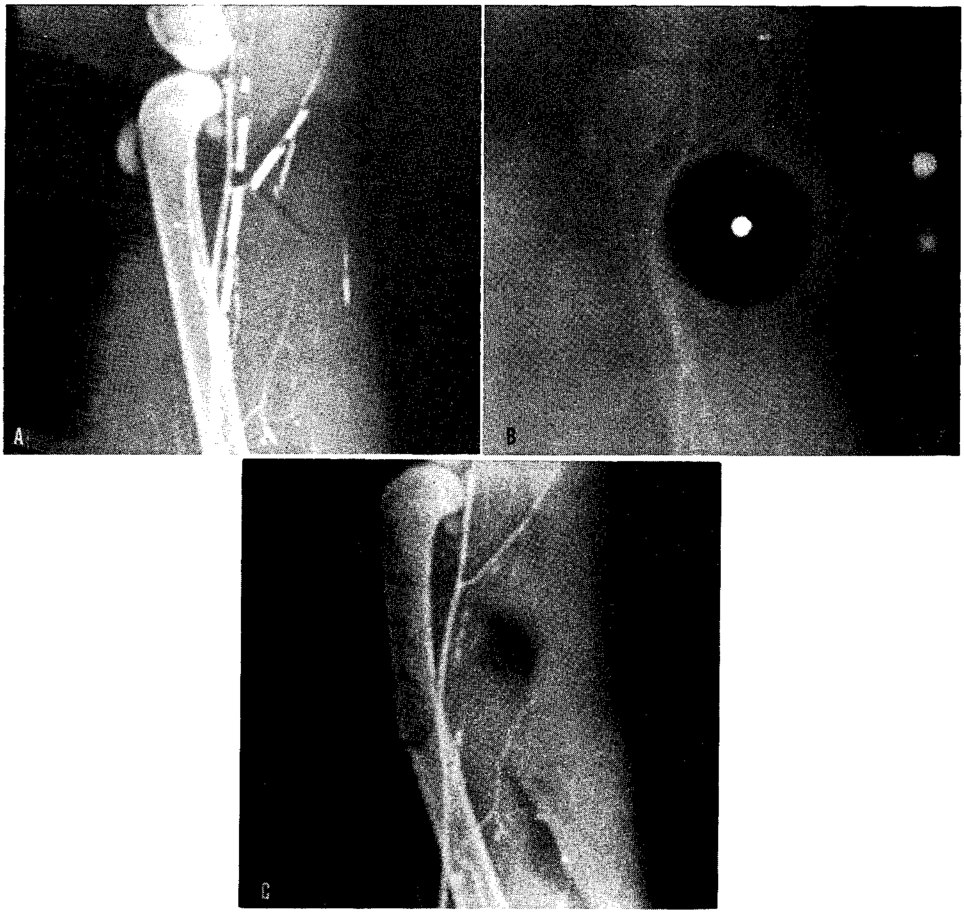

FIGURE 113.—Roentgenograms of the thigh of a cat. A. Roentgenogram (No. 245) showing femoral artery and vein injected with barium sulfate. B. Microsecond roentgenogram showing displacement of the blood vessels by the large temporary cavity formed after the passage of a $\frac{5}{32}$-inch steel sphere with an impact velocity of 3,200 f.p.s. The dark circular temporary cavity is shown in cross section with missile hole in center. C. Roentgenogram made immediately after the shot. Note that the vessels have returned to their original positions and that the femur is fractured. The permanent cavity shows as a dark area to the right of the blood vessels.

of an undamaged control sciatic nerve of a cat. Figure 116 is a similar photomicrograph of a nerve in which conduction was blocked. This figure shows that the nerve fibers have been widely separated and that many fibers are completely severed, with their ends badly frayed. A critical study of many of the fibers at very high magnifications indicated that the axis cylinders of many of them were broken, but the myelin sheath and neurilemma showed no signs of damage. Figure 117 shows a section from another nerve. In this

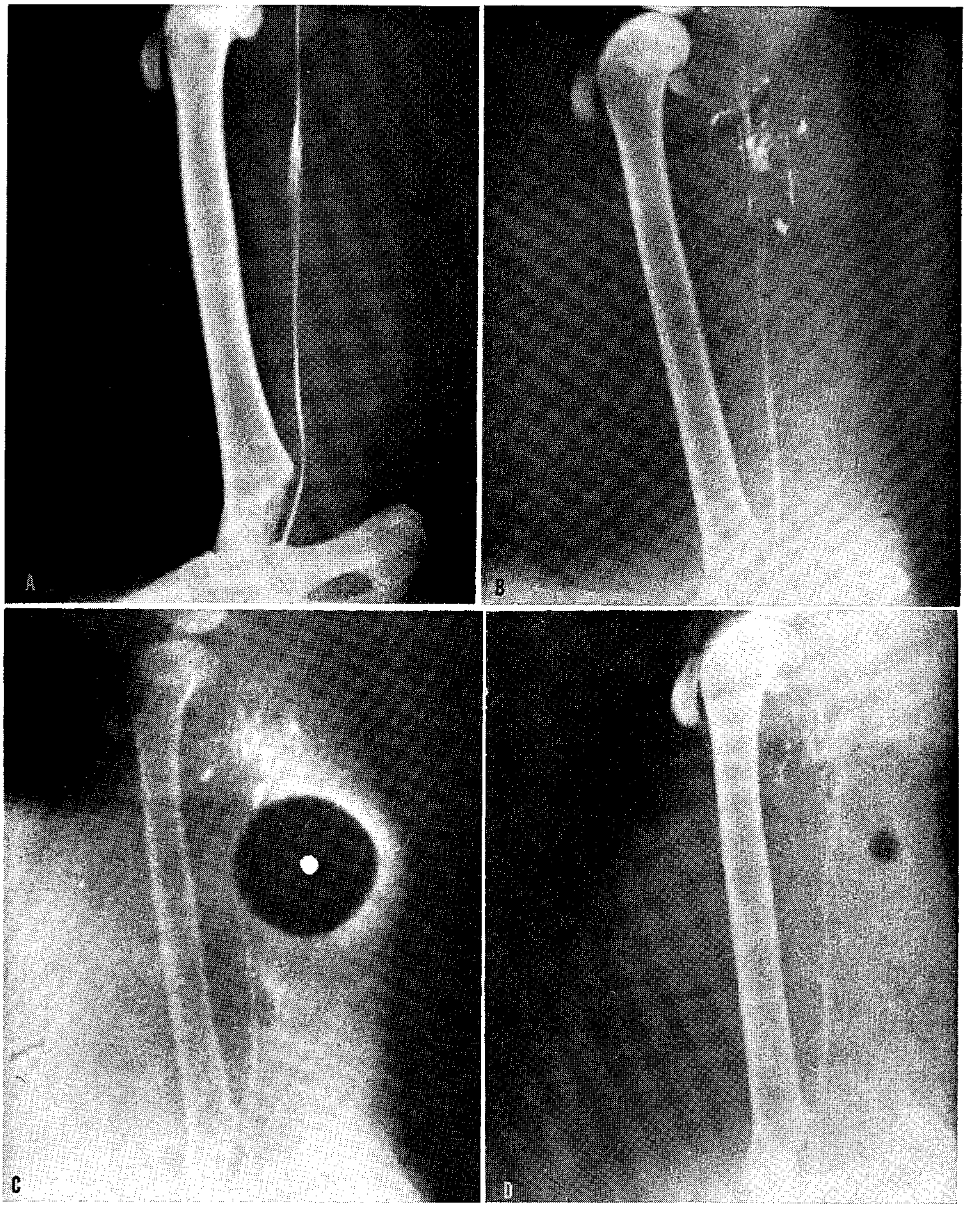

FIGURE 114.—Roentgenograms of the thigh of a cat. A. Roentgenogram (No. 228) showing the sciatic nerve made radiopaque with iodobenzene. B. Roentgenogram (No. 232) made immediately before a shot. C. Microsecond roentgenogram showing the displacement of the sciatic nerve by the temporary cavity (seen in cross section; missile hole in center) which is formed after the passage of a 5/32-inch steel sphere whose impact velocity was 3,200 f.p.s. D. Roentgenogram made immediately after the shot. Note relation of the permanent cavity (small dark area) to the nerve.

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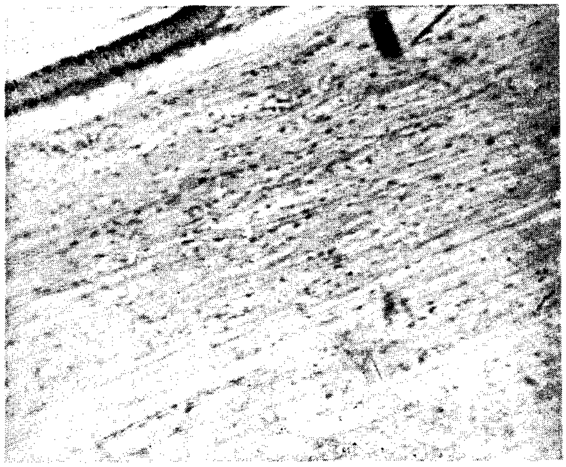

FIGURE 115.—Photomicrograph of a section of an undamaged control sciatic nerve of a cat.

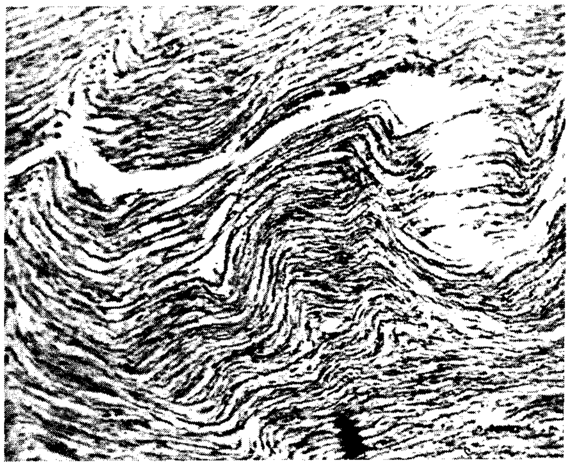

FIGURE 116.—Photomicrograph of a section of the sciatic nerve of a cat, showing type of damage produced by a $\frac{4}{32}$-inch steel sphere which did not strike the nerve directly. Note the separated and broken nerve fibers.

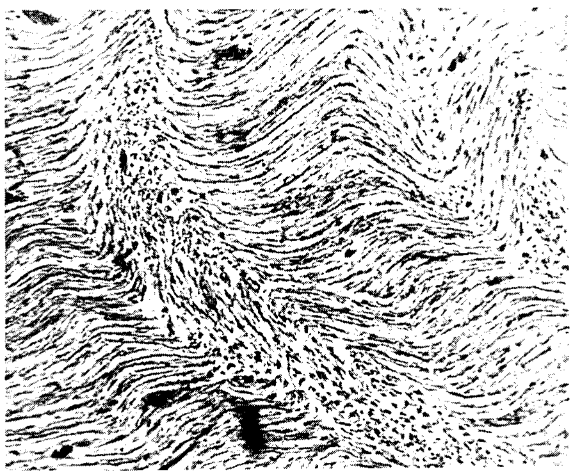

FIGURE 117.—Photomicrograph of a section of the sciatic nerve of a cat, showing type of damage produced by a $\frac{4}{32}$-inch steel sphere which did not strike the nerve. Note the manner in which the nerve fibers are kinked.

case, the nerve fibers have been thrown into prominent kinks, as though they had undergone abnormal stretching. In all of the cases described here, the nerve sheath (epineurium) appeared undamaged.

PRESSURE CHANGES ACCOMPANYING THE PASSAGE OF MISSILES

When a high-velocity missile strikes the body and passes through soft tissues, three kinds of pressure change appear: (1) Shock wave pressures, or sharp high-pressure pulses, formed when the missile hits the body surface; (2) very high pressure regions immediately in front and to each side of the moving missile; (3) relatively slow low-pressure changes connected with the behavior of the large explosive temporary cavity formed behind the missile.

Some characteristics of shock waves in water have already been considered (pp. 152–158). Attention was also directed to the high-pressure regions around the moving sphere, whose effects are seen in figure 60. Shock wave pressures and cavity pressure changes in the body can be investigated in two ways: (1) The pressures can be accurately recorded by a proper type of gage, or (2) their existence can be visualized in models simulating conditions found in the body. For accurate recording, a calibrated tourmaline piezoelectric crystal gage was placed in the stomach of the deeply anesthetized animal which was then shot through the posterior part of the abdomen. The method is described on pages 147–152. In order to record shock wave pressures, the amplifier gain was low and the sweep rapid, calibrated in microseconds. To record pressure changes around the temporary cavity, the gain was high and the sweep relatively slow, calibrated in milliseconds.

For visualizing the shock wave pressures, the spark shadowgram method described on page 150 was used. The tissue, placed on the surface of a tank of Ringer's solution, was shot with a high-velocity missile and the spark triggered to catch the shock waves as they moved from tissue to solution; or the tissue was suspended in the solution and the behavior of shock waves on reflection or transmission recorded.

Shock waves in tissue arise at the impact of the missile with the skin or other tissue surface. The velocity of shock waves in tissue is approximately the same as in water, 4,800 f.p.s. The chief difference in behavior of shock waves in the body, as compared with water, is associated with the heterogeneity of the tissues. The wave is dispersed on transmission through, or on reflection from, surfaces. Instead of a single clean wave, there appears a mass of wavelets with a series of high-pressure peaks. Figure 118 shows a shock wave in water partially reflected and partially transmitted by a slab of gelatin gel suspended in the tank. The gelatin is sufficiently homogeneous to give good reflection. Figure 119A shows waves which have arisen in, and passed out of, a mass of thigh muscle suspended at the surface of Ringer's solution. Figure 119B shows a shock wave which has originated from a thigh muscle surface. In both cases, the dispersion of the wave is apparent.

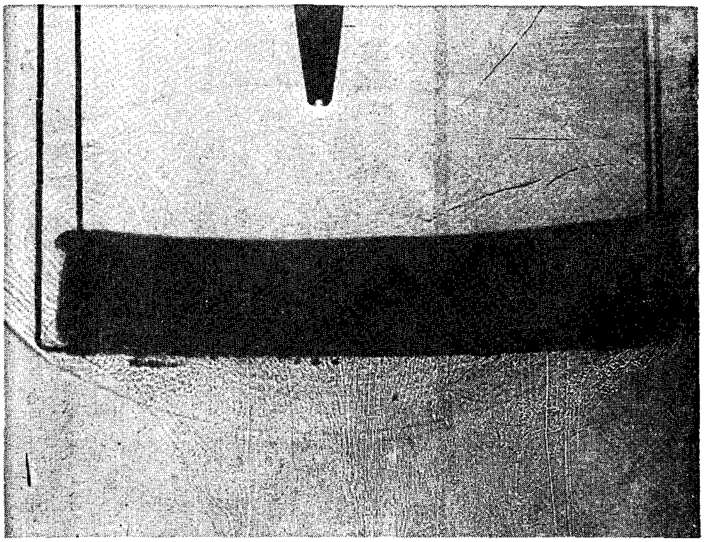

FIGURE 118.—Shadowgram (P 132) of a wave reflected from and transmitted through a 1¼-inch block of 20 percent gelatin gel suspended in water. The original wave, from a 3⁄16-inch steel sphere with an impact velocity of about 2,500 f.p.s. can be seen at each side of the block.

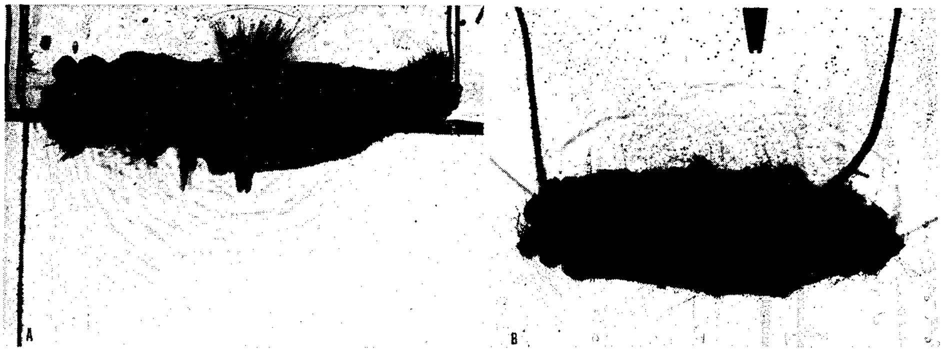

FIGURE 119.—Shadowgrams of a shock wave. A. Shadowgram (S 115) of wave whose origin is at the upper surface of a fresh skinned thigh of a cat. The wave has been dispersed and passed from the tissue to water. B. Shadowgram (S 143) of a wave arising at the surface of water and reflected from a fresh skinned thigh of a cat suspended in water. Note the convection trails below the muscle tissue.

Reflection and transmission also occur from a piece of cat's stomach spread on a frame, as illustrated in figure 120. The behavior of a shock wave at the body wall is illustrated in figure 121, which shows a piece of the abdominal wall (skin and muscle) of a cat stretched on the surface of a tank of Ringer's solution. The tank has then been penetrated by a horizontal shot (to right). The shock

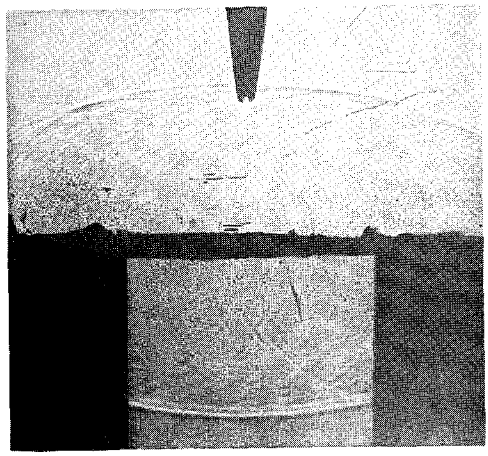

FIGURE 120.—Shadowgram (P 130) of a wave in Ringer's solution after reflection from and transmission through a piece of cat stomach stretched on a frame. The wave arose from a $\frac{3}{16}$-inch steel sphere with an impact velocity of 3,000 feet per second.

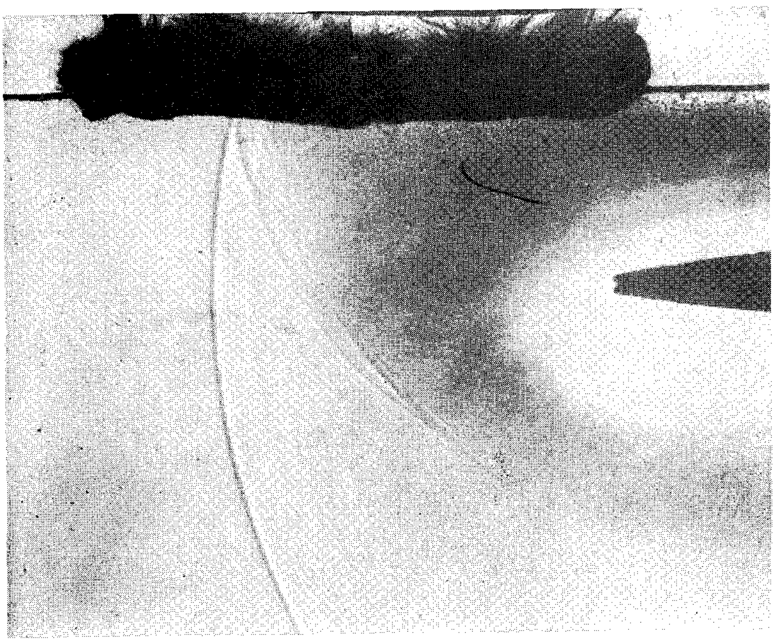

FIGURE 121.—Spark shadowgram (P 201) of a shock wave reflected from the inner surface of cat's abdominal wall, which is resting on the surface of Ringer's solution. The cone-shaped cavity behind the $\frac{3}{16}$-inch steel sphere, which hit the tank horizontally with a velocity of 3,000 f.p.s., is at right. The reflected wave is not so regular as the incident wave and has a light band forward, indicating that it has been inverted to a tension wave on reflection. The low pressure resulting from inversion is indicated by the cavitation, which appears as fine black dots. The secondary waves following the shock wave are due to vibration of the steel sphere. The missile is 6 cm. below the surface of the water.

wave can be seen toward the left and has been reflected from the undersurface of the body wall. Note that a light band precedes the dark band of the shock wave, indicating that, on reflection, a pressure pulse has been changed to a tension pulse. Such reversal occurs whenever the acoustic impedance (defined as the density multiplied by the wave velocity) of the reflecting medium is less than that of the medium in which the wave was moving. At an air surface, the pressure wave is always reflected as a tension wave.

Reflection from bone, in this case the surface of a human skull suspended in water, is illustrated in figure 122, while figure 123 depicts a row of beef

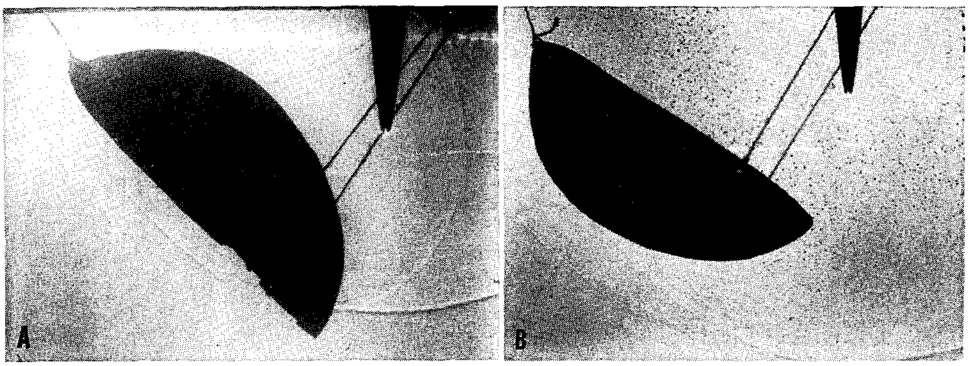

FIGURE 122.—A. Shadowgram (P 158) of wave in water reflected from the outer surface and also transmitted by a top section of water-soaked human skull. The original wave from a ⅛-inch steel sphere, with impact velocity of about 3,000 f.p.s., can be seen near the lower right corner of the bone. B. A wave transmitted through a skull section.

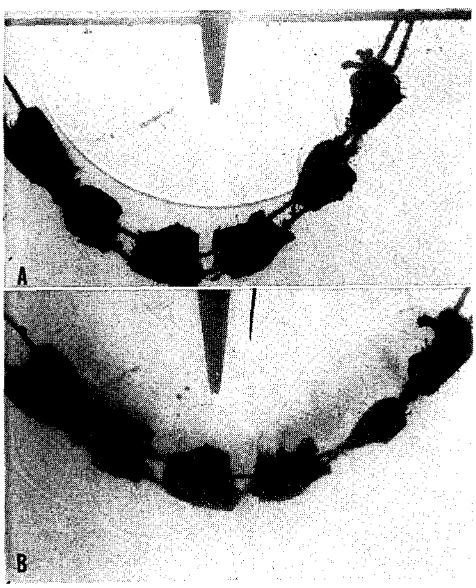

FIGURE 123.—A and B. Shadowgrams (S 147 and S 148) showing reflection and transmission of water shock waves by a rack of beef ribs seen in cross section, imitating the thorax. The ⅛-inch steel sphere had an impact velocity of 3,000 f.p.s. Note the reflection of waves (A and B) and the origin of new wavelets in the space between the ribs (B).

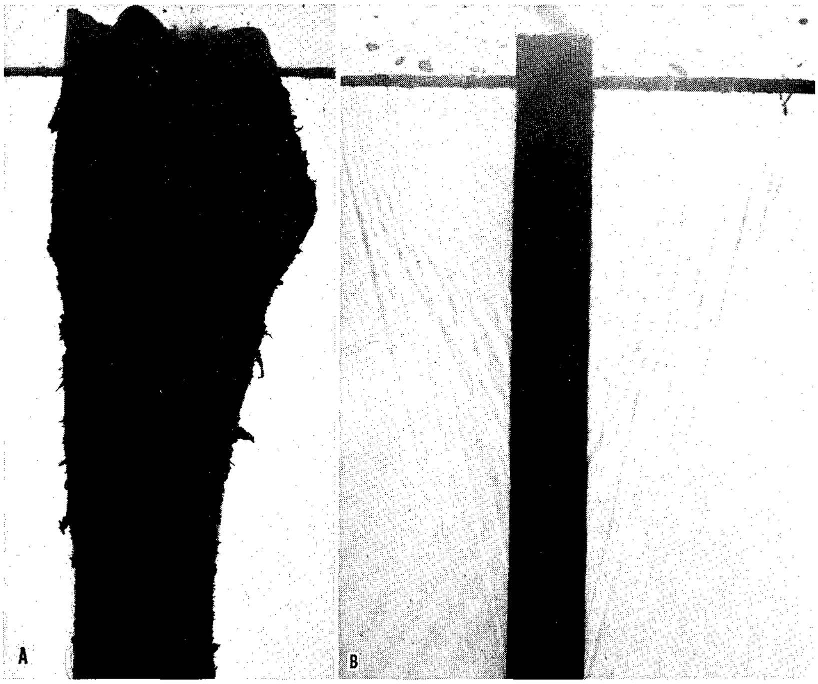

FIGURE 124.—Shadowgrams of a beef femur and a steel bar almost completely immersed in water. The top of each has been struck by a ⅛-inch steel sphere moving 3,000 f.p.s. Note that the shock waves within the steel bar have passed into the water but that no such waves pass out of the bone. A. Shadowgram (S 129) of beef femur. B. Shadowgram (P 128) of steel bar.

ribs (seen in cross section) tied together so as to represent the skeleton of the thoracic wall. Reflection from each bone is clearly apparent, as well as the secondary wavelets formed when a shock wave moves through the opening between ribs.

Shock waves do not appear to pass into water when a bone is hit directly by a high-velocity missile. Figure 124A is part of a beef femur whose upper end has been struck. No waves are visible moving from the bone to water, as appear when a bar of steel, shown in figure 124B, is substituted for the bone.

Tourmaline crystal pressure records of four shock waves in the abdomen of a cat are reproduced in figure 125. It will be observed that these records differ from a shock wave in water in that the descending limb of the pressure peak is steep and the shock waves themselves are often multiple. In all these records, the pressures stop abruptly at a certain point. This is an artifact due to blocking of the piezoelectric amplifiers by the surge of current through the microsecond X-ray apparatus used to record conditions within the abdomen at the time the pressure record is made. Such a microsecond roentgenogram is reproduced in figure 126.

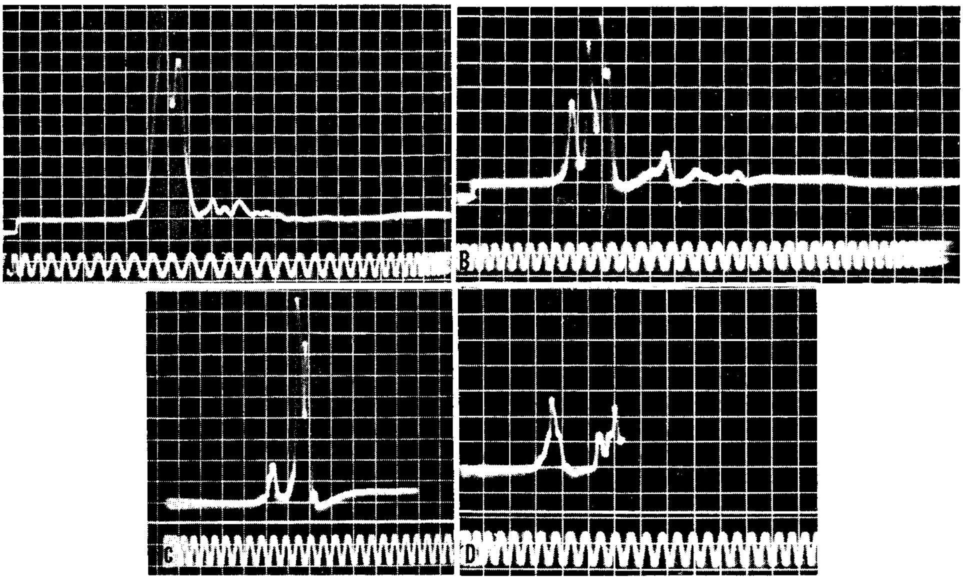

FIGURE 125.—Four records of shock wave pressures (crystal in stomach) from four different cats shot through the abdomen with a 3/16-inch steel sphere moving 3,800 f.p.s. Time in 100 kilocycles. One vertical division in A (cat 360) is 193 pounds per square inch; in B (cat 362), 188 pounds per square inch; in C (cat 333), 162 pounds per square inch; and in D (cat 331), 171 pounds per square inch.

FIGURE 126.—Microsecond roentgenogram of the abdomen of a cat showing the crystal pressure gage in position, taken during the passage of a 3/16-inch steel sphere (at right) with striking velocity of 3,800 f.p.s. The trigger screen for the X-ray surge is at left. Note the large temporary cavity which has expanded around the barium sulfate filled stomach. The pressure record for this figure is reproduced in figure 125C.

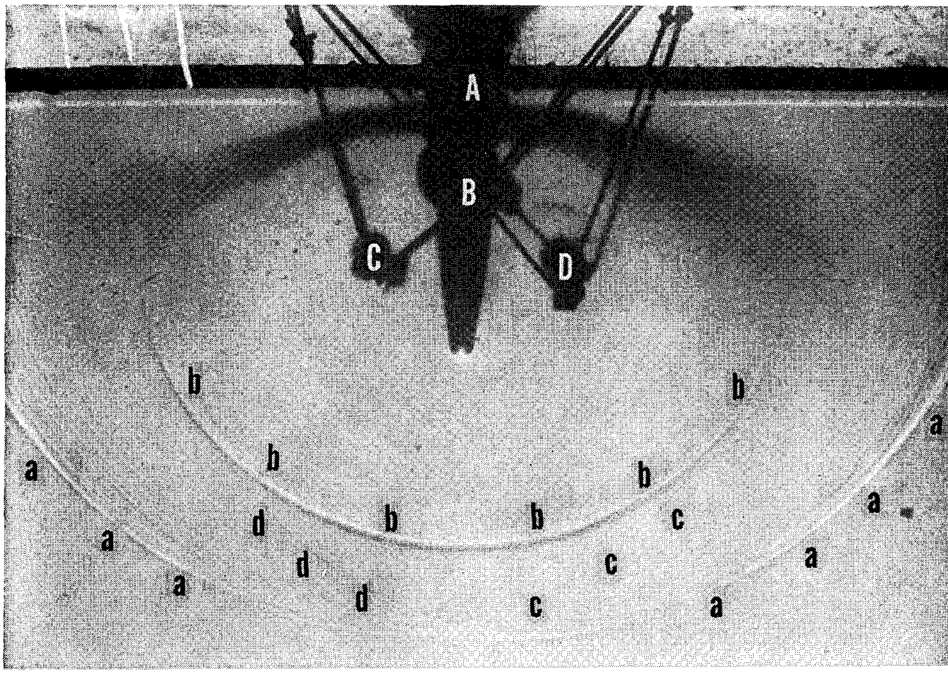

FIGURE 127.—Spark shadowgram (P 199) of a shock wave complex from a 3/16-inch steel sphere which has struck the water surface with a velocity of 3,800 f.p.s. and moved through a gas-filled segment of the colon of a cat. Two other gas-filled segments of the intestines of a cat are to right and left. Capital letters indicate the origin of waves and small letters the wave front. Depending upon the position of the crystal, various types of pressure record would be obtained.

It will be noted from figure 125 that the first pressure pulse of a series may not be so high as the succeeding pulses. This can be explained in part by the reflection of shock waves in the abdomen and in part by the presence of gas pockets in the alimentary tract. Whenever a missile perforates a gas pocket and enters tissue on the opposite side, a new shock wave will be generated. Since the new wave is nearer the crystal, its peak will be higher than the original one started at the body wall. It is not possible, therefore, to present a typical record of shock waves in the abdomen, since so much depends upon reflection and distribution of gas in any particular case.

The manner in which a series of shock waves could appear within the abdomen is illustrated in the spark shadowgram of figure 127, which shows three loops of a cat's colon, each containing an air pocket, suspended in Ringer's solution in the form of a triangle. A shot was fired through one loop of colon and shock wave A—a was formed at the liquid surface. This wave was reflected from each of the other loops of colon and shock waves B—b and C—c were formed. When the shot had passed the gas mass and

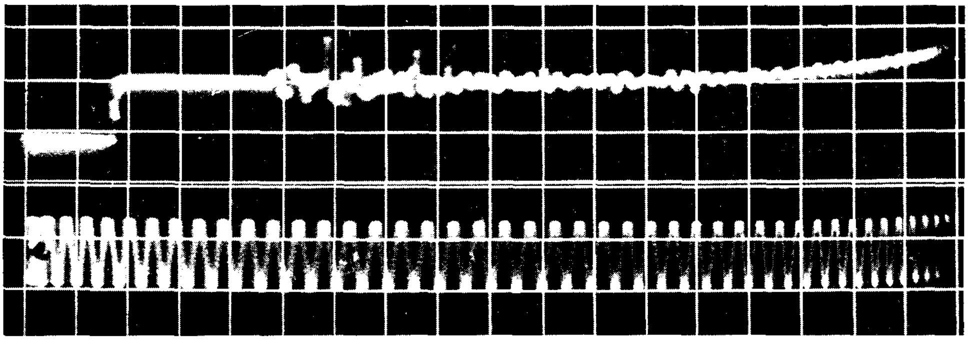

FIGURE 128.—A crystal record of pressure changes in the stomach of a cat when the thigh is shot with a 3/16-inch steel sphere moving 3,800 f.p.s. Time in 100 kilocycles.

hit the further side of the middle piece of colon, another large shock wave was formed, D—d. If a crystal had been placed at X, it would have recorded a medium, followed by a weak and then a strong shock wave, giving a multiple record somewhat like that of figure 125.

When the crystal is in the stomach and the animal is shot through the thigh, about 14 cm. from the crystal, the type of pressure record shown in figure 128 is obtained. There results a jumble of small pressure peaks about 5 microseconds apart and of an intensity of about 10 to 20 pounds per square inch. The pressure record is very similar to what might be expected from the appearance of the shock shadowgram shown in figure 119B.

The relatively slow pressure changes in the cat's abdomen, recorded from a crystal gage in the stomach, are reproduced in figure 129. The timing is in milliseconds. The first peaks mark the shock wave, whose pressure is so great as to rise completely off the record. From measurements of the high-speed motion picture of the shot, taken simultaneously with the pressure record and reproduced in figure 130, it is found that the second maximum pressure corresponds to the collapse of the temporary cavity. The subatmospheric pressure between the shock wave and the second pressure peak corresponds to the maximum of the temporary cavity, visible as two prominent bulges, as shown in frames 3 and 11.

After the large temporary cavity collapses, microsecond roentgenograms show no second expansion, such as occurs after a shot into a tank of water. Although the motion picture of the cat's abdomen does show indications of new wrinkled bulges on each side of the abdomen, these second bulges merge with the subsequent distortion of the abdomen. The two small pressure oscillations in the pressure record appear to have no counterpart in the external movements of the abdomen, visible in the motion picture. The pressure record is, in fact, quite flat during the long period of wavelike abdominal movements.

In the respect just mentioned, a shot into the body differs from a shot into water in a tank, where pulsations of the gas making up the temporary

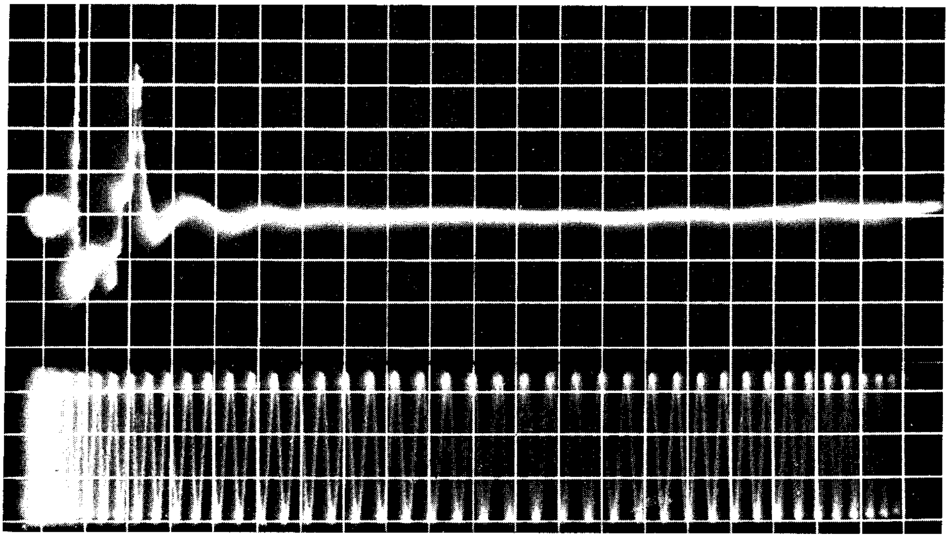

FIGURE 129.—A crystal record of pressure changes in the abdomen of a cat shot with a $\frac{3}{16}$-inch steel sphere moving 3,000 f.p.s. The time curve is 1000 cycles, and the vertical pressure divisions are 13.1 pounds per square inch. The shock wave at left moves off the screen and is indicated by the line of white ink. There follows a subatmospheric-pressure period which corresponds to the expansion of the temporary cavity and then a pressure peak (3.5 milliseconds after the shock wave) that is represented by frame 11 of figure 130. The later pressure oscillations are believed to be due to pulsation of gas pockets in the intestines. (24 Jan. 1946, cat 364.)

cavity is a striking phenomenon and the pressure changes during these pulsations are found to agree exactly with the expansion (decreased pressure) and contraction (increased pressure) of the cavity, illustrated in figure 60.

It is very probable that the opening made by the shot in the body wall closes almost immediately, so that little air can rush in behind the missile. In an animal, therefore, the initial large temporary cavity may be considered as almost entirely filled with water vapor. When the cavity collapses, only small pockets of gas are left, comparable in volume and scarcely distinguishable from the gas pockets already present in the intestine. In the pressure record of figure 129, the pulsation of these gas pockets is represented by the small pressure oscillations, spaced 2 to 3 milliseconds apart. They are quite comparable to the pulsation observed in small submerged balloons when a sphere is shot into a tank of water.

Small balloons, filled with air and suspended in a tank of water, are instructive for visualizing pressure changes around the temporary cavity resulting from a shot into the tank (fig. 131). As can be seen, the balloons are at first contracted by the high pressure of the shock wave, but very quickly they expand to a large size, as a result of the decreased pressure during expansion of the cavity. In addition to the expansion and contraction of the balloons, synchro-

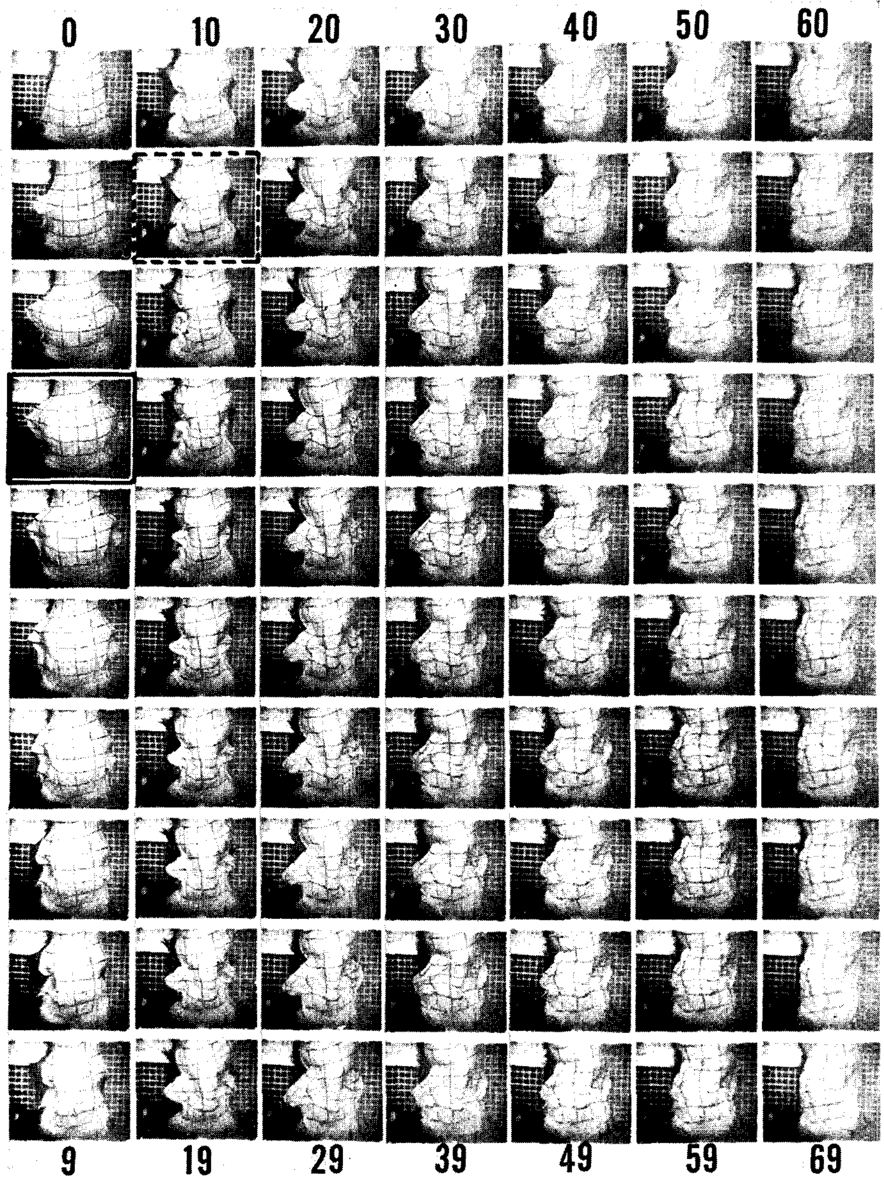

FIGURE 130.—Frames (2,360 per second) from a high-speed motion picture of the abdomen of a cat, shaved and marked with black lines 1 inch apart. A $\frac{3}{16}$-inch steel sphere has perforated the abdomen from the left. Frame 3 is that of the maximum temporary cavity and corresponds to the maximum subatmospheric pressure of figure 129. Frame 11 corresponds to the first pressure peak after the shock wave.

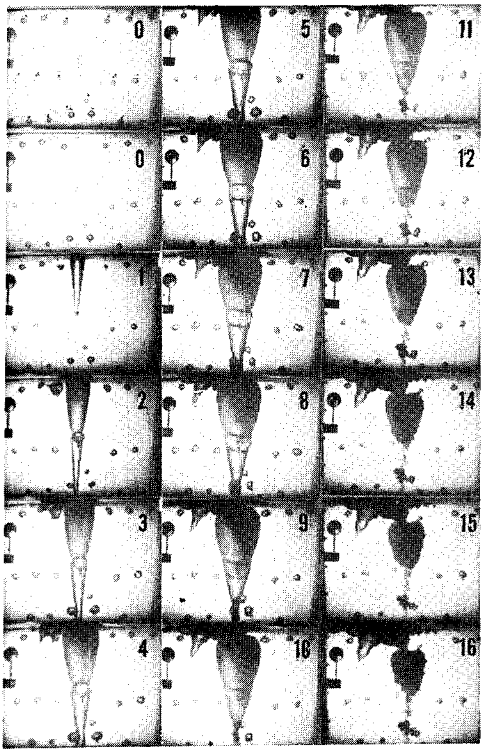

FIGURE 131.—Frames (2,160 per second) from a motion picture (166) of a ⅛-inch steel sphere (impact velocity 3,000 f.p.s.) striking the surface of water (at top of each frame) in which are suspended small rubber balloons. The development of the temporary cavity is well shown. Pressure changes in the water are indicated by contraction and expansion of the balloons. The vertical dots on left are 5 cm. apart.

nized with the volume changes of the cavity, they also pulsate with their own period (about 500 a second), and in this respect they serve as models for the behavior of small gas pockets in the body.

The importance of gas pockets in tissues in relation to pressure changes has been emphasized in the foregoing discussion. That these gas pockets are important in wounding can be determined by suspending in Ringer's solution small masses of tissue, with and without gas pockets, and then shooting into the solution near the tissue masses. Excised hearts of frogs have been used to investigate the mechanism of wounding by this method.

When isolated frog hearts containing no gas are fixed in position in a tank of Ringer's solution, it has been determined that damage from a shot into the solution occurs only when the hearts are rapidly stretched on their moorings by the expansion of the temporary cavity. They suffer no damage from shock waves beyond the boundary of the temporary cavity. The arrangement of such an experiment is illustrated in figure 132. Only the hearts engulfed by the cavity, or greatly stretched by it, were damaged.

In order to eliminate the cavity formation, a piece of armorplate was placed on the water surface and struck by a very high velocity missile. By this method, shock waves of great intensity can be produced, but only a minute cavity forms underneath the armorplate. Water movement is thereby reduced to a minimum. It was found that these high-intensity shock waves did not

affect frog hearts suspended underneath. However, if gas has first been injected into a heart, as in A and F of figure 133, the sudden expansion of this gas from negative pressures in the water around the minute cavity was found to cause damage. The A heart (near the small cavity) was seriously injured, while the F heart (farther away) suffered no severe damage.

These, and other similar experiments, indicate that it is the subatmospheric pressure around the temporary cavity, recorded in the crystal records of figures 60 and 129, that causes the damage and that this damage results from the expansion of gas pockets rather than from the high pressures connected with the shock wave. Damage by gas expansion may be spoken of as secondary damage, whereas damage from expansion of the temporary cavity itself is primary damage. In both cases, the destructive effects are due to severe tearing of tissue.

A striking demonstration of gas effects is illustrated in figure 134 which shows a loop of cat intestine, with an air bubble within the right end, suspended

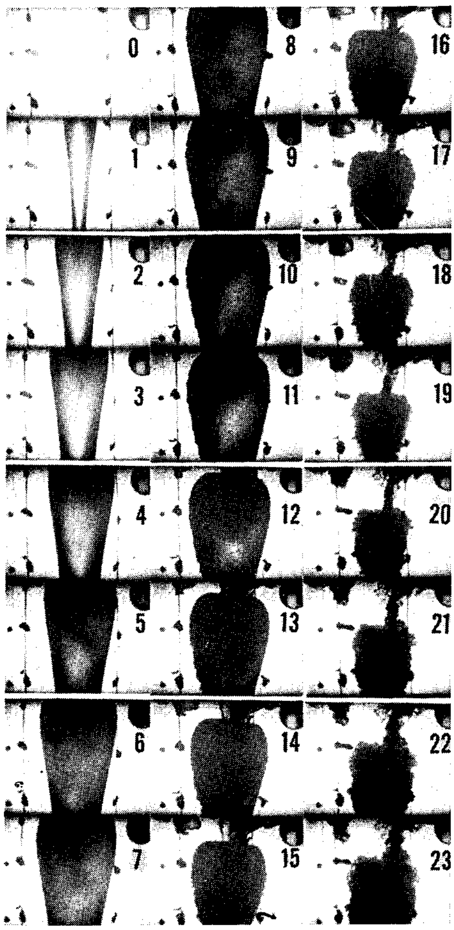

FIGURE 132.—Frames (2,400 per second) from a motion picture (168) of six frog hearts tied to two vertical strings in a tank of Ringer's solution. The surface of the water is at the top edge of each frame. A ⅛-inch steel sphere, with impact velocity of 3,100 f.p.s., penetrated the solution between the vertical rows of hearts, and the development of the temporary cavity is clearly seen. The effect on the hearts is described in the text. The vertical dots on left are 5 cm. apart. The circle in upper left is a mirror reflection of a sodium lamp flashing 120 times a second.

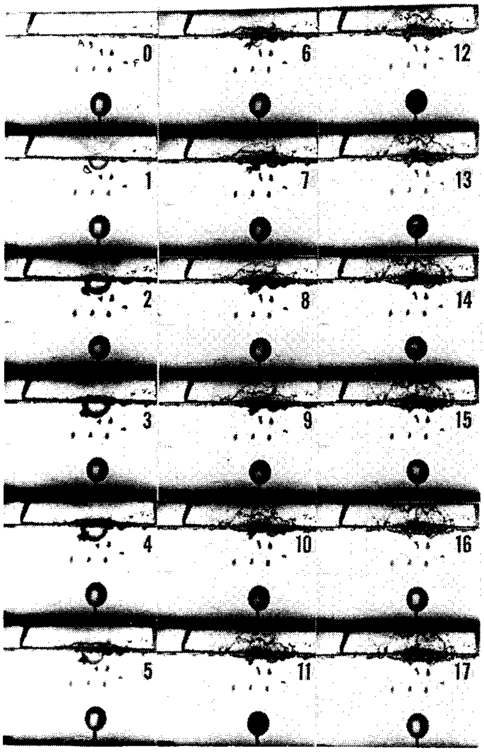

FIGURE 133.—Frames (above 2,000 per second) from a motion picture (SW 5) of six frog hearts tied to horizontal strings (invisible) below a sheet of armorplate which has been struck (without perforation) by a ⅛-inch steel sphere moving about 4,000 f.p.s. A small cavity appears under the plate in frames 1 to 6. The upper left (A) and lower right (F) hearts contain air, and the expansion of the air in the upper left heart is clearly visible. The effect on the hearts is described in the text. The horizontal lines at left are 5 cm. apart. A circular mirror in lower middle of each frame reflects a sodium lamp flashing 120 times a second.

in a tank of Ringer's solution. When a shot is fired through the ring of intestine, the gas bubble at the right can be seen to first contract and then expand markedly. When the intestine was later examined, the mucosa and submucosa were found to have been perforated in the gas-containing region, although the muscularis layer was intact. Such effects are exactly comparable to damage to the human body from underwater blast. This damage is restricted to gas pockets in the alimentary canal, leading to intestinal perforation, or to gas in the lungs, where severe hemorrhage occurs. Although secondary damage from gas is important in rifle shots, it never equals the primary damage which results from the expansion and tearing caused by the formation of the temporary cavity.

RETARDATION OF MISSILES BY SOFT TISSUE AND TISSUELIKE SUBSTANCES

The slowing down or retardation of a missile as it traverses tissue is an important factor in determining how and where the missile delivers its energy to the tissue. In order to understand the mechanism of wounding, it is essential to know the law of force which retards the missile. Here, the studies of retardation in water and in 20 percent gelatin gel are very helpful. It has

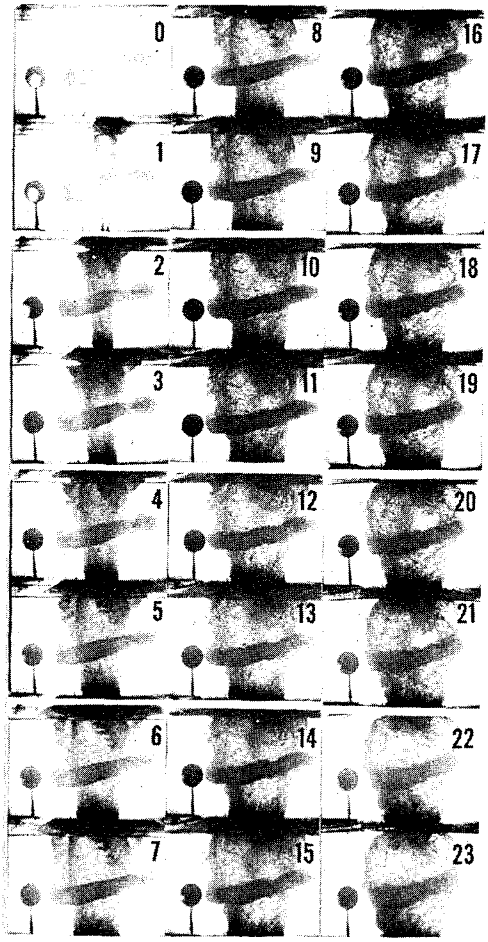

FIGURE 134.—Frames (2,280 per second) from a motion picture (173) of a loop of cat colon with an air pocket in the right end, suspended in a tank of Ringer's solution. A ⅛-inch steel sphere with a velocity of 3,100 f.p.s. entered the water and passed through the center of the loop of colon without hitting it. The large temporary cavity can be seen to expand and touch the colon. Note especially the slight constriction of the air pocket in frame 1 and its expansion in frames 2 to 5. The distance between horizontal lines at left is 5 cm.; the timing mirror is also at left in each frame.

been found that the retardation, dV/dt, is proportional to the square of the missile's velocity, V. This is usually written $dV/dt = -\alpha V^2$. α is called the retardation coefficient, V is the instantaneous velocity of the missile, and T the time. The retardation of the missile at high velocities is produced almost entirely by the inertia of the water and gel which was originally in the missile's path and which is forced aside. Since the inertia depends only on the density, it is to be expected that soft tissues, gelatin, and water will behave in nearly the same manner. This proves to be the case—all three offering a resistance to the missile which is proportional to the square of the missile's velocity.

The retardation coefficient of a ⅛-inch steel sphere in water, gelatin gel, and muscle has been measured and is as follows:

Water	0.091 cm.$^{-1}$
20 percent gelatin gel (24°C.)	.106 cm.$^{-1}$
Cat muscle (living)	.136 cm.$^{-1}$

Living cat muscle, therefore, is only 50 percent more retarding than water and only 28 percent more retarding than gelatin gel.

These retardation coefficients for missiles were calculated from the loss of velocity which a sphere experienced in going through the thigh of a deeply anesthetized cat. The length of the missile track was also used in the calculation. The retardation coefficients in water and gelatin gel were calculated from the position-time relationship as measured from the high-speed motion pictures. The retardation coefficient, α, is equal to $\frac{\rho}{2}\frac{A}{M}CD$ where A is the projection area, M the mass, ρ the density of the medium, and CD the drag coefficient. The measured values of CD for these three substances were: Tissue, 0.45; 20 percent gelatin gel at 24° C., 0. 35; and water, 0. 30.

A sphere or nontumbling fragment loses its energy rapidly in traversing soft tissues and waterlike substances. The energy, E, falls off exponentially with penetration distance, s, as follows: $E=E_0e^{-2\alpha s}$. A ⅛-inch steel sphere loses half its impact energy after penetrating 2.22 cm. of muscle and nine-tenths of its energy after penetrating 8.3 centimeters. A 1/16-inch sphere will lose these same percentages of energy in just half these distances, while a ¼-inch sphere will require twice the distance.

In the case of high-velocity missiles, certain characteristics of the explosive or temporary cavity are related to the energy dissipated by the missile. It is possible, therefore, to determine how and where the missile lost its energy simply by inspecting a microsecond roentgenogram of the temporary cavity. It turns out that the diameter of the temporary cavity, D (measured perpendicular to the missile path) is proportional to the square root of the space rate of energy change or $D=(8\ k\ \alpha\ E/\pi)$, where k is a constant having an experimentally measured value of 8.92×10^{-7} cm.^{3}/erg for water and 0.80×10^{-7} cm.^{3}/erg for living muscle of a cat thigh.

This decrease in energy is clearly observable in a cavity produced in water by its decrease in diameter as the missile is slowed down (fig. 135). This is also shown in figure 75, where a cavity in the thigh can be seen to be wide near entrance and narrow near exit.

The rate at which energy is lost and the cavity diameter also increase with the ratio A/M, which is the ratio of projection area to mass of the missile. This signifies that a missile of large projection area and small mass will lose energy rapidly and will produce a wide, but short cavity. When two spheres of different masses having the same projection area and velocity are allowed to enter the water, the light sphere loses energy rapidly, producing a short, but wide cavity. This is shown in figure 136 (S25, S59) where the dissipation of energy by an aluminum (left) and a steel (right) sphere is contrasted.

When a fragment is shot, tumbling of the fragment changes the projection area, and this change is reflected in the shape of the cavity. Several cavities, formed by tumbling missiles, are shown in figures 56 and 137. This phenomenon is also shown in figure 88, where a cavity in the abdomen of a cat was formed by a tumbling cylindrical fragment (a section of a wire nail).

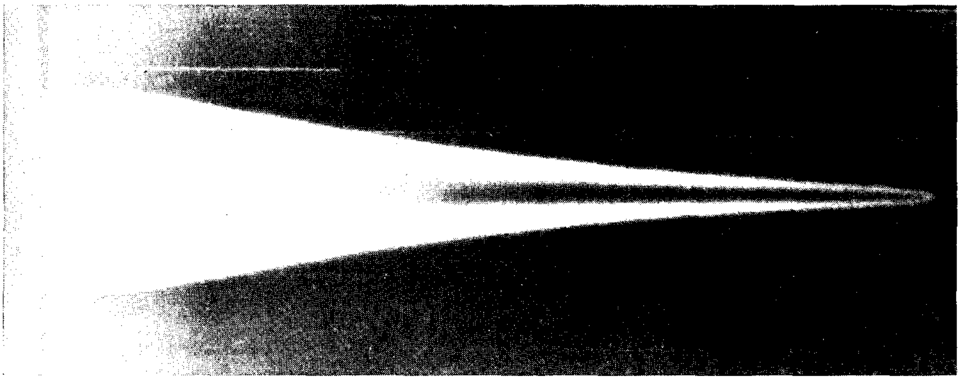

FIGURE 135.—A frame from a high-speed motion picture of the cavity formed by a steel sphere, showing that its diameter (measured perpendicular to the bullet path) falls off as the energy of the sphere decreases. The diameter is proportional to velocity of the missile at any instant. Water surface is at left.

The retardation suffered by small steel spheres when traversing human skin was also measured. This was done by mounting several layers of skin in the path of a small steel sphere and measuring the velocity before and after impact. Figure 138 shows the skin pocket mounted in the middle of a shock wave velocity recorder. The inclination of the lines of dashes gives the before and after velocity of the missile. The missile is traveling from right to left.

For equivalent thicknesses, the retardation coefficient for skin was 40 percent larger than that of muscle. The velocity lost by a ⅛-inch steel sphere when perforating 8 cm. of skin was found to be $0.182(V_o-170)s+170$, where the velocity is expressed in feet per second. The 170 f.p.s. represents the velocity required to enter the skin without penetrating it. For other missiles, the relationship just cited may be extrapolated to give $0.30\ AM^{-1}(V_o-170)s+170$. The effect which skin exerts on certain missiles has been calculated from this formula, and the results are as follows:

¹⁄₁₆-inch sphere:		
Impact velocity	f.p.s.	3, 000
Velocity lost	f.p.s.	370
Velocity loss	percent	12. 3
Energy loss	do	24. 6
¼-inch sphere:		
Impact velocity	f.p.s.	3, 000
Velocity lost	f.p.s.	235
Velocity loss	percent	7. 8
Energy loss	do	15. 6
.30–06 bullet:		
Impact velocity	f.p.s.	3, 000
Velocity lost	f.p.s.	175
Velocity loss	percent	5. 8
Energy loss	do	11. 6

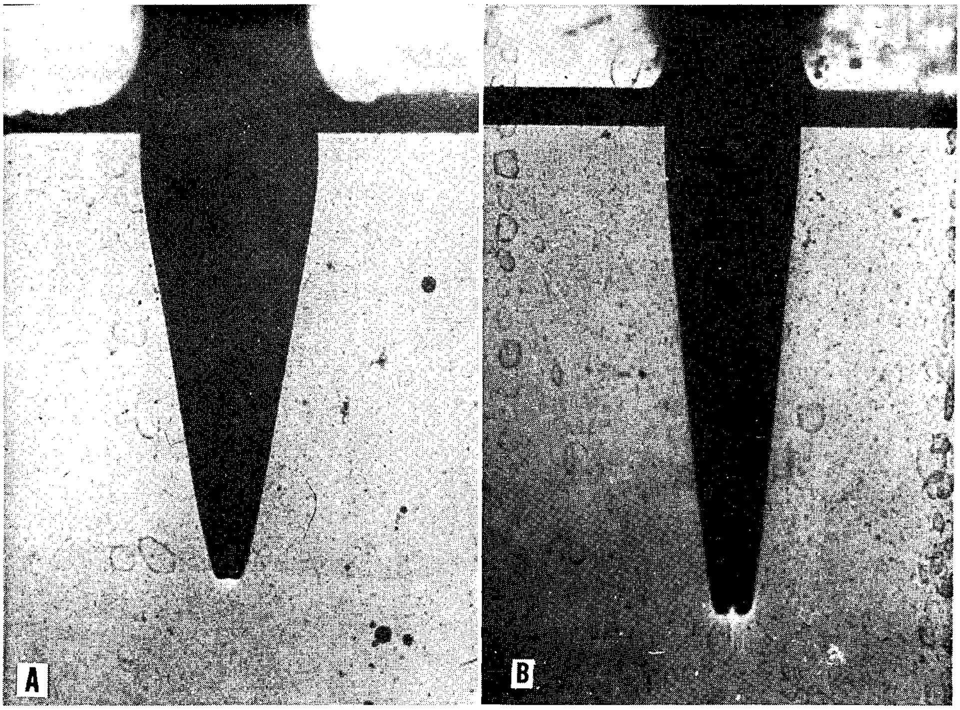

FIGURE 136.—Spark shadowgraphs of cavities formed by an aluminum sphere and a steel sphere. Both were traveling with velocities of about 3,000 f.p.s. Note the short, wide cavity of the aluminum sphere (A), indicating that it lost energy at a more rapid rate than the steel sphere (B). A. Shadowgraph (S 25) of ⅛-inch aluminum sphere. B. Shadowgraph (S 29) of ⅛-inch steel sphere.

PENETRATION OF MISSILES INTO SOFT TISSUE AND BONE

When wound damage to various internal organs of the body, vascular channels, and nerves is to be considered, the question of how deeply a missile can penetrate different types of tissues becomes a highly important one. Various soft tissues, but more particularly bone, often overlay and serve as a protective layer to important structures underneath. This section presents data which have been secured regarding the problem of penetration.

The distance which a missile travels into soft tissue before being brought to rest depends not only on its impact velocity, V_o, but also on its projection area, A, its mass, M, and its shape factor, F. Such an inference can be drawn from studies on penetration in a tissuelike substance as 20 percent gelatin gel. That the law of penetration for tissue should be the same as the law for gelatin follows from the observation that they both obey the same retardation law.

The penetration, P, into 20 percent gelatin gel at 24° C. by steel spheres is given by $P=\alpha^{-1}\ 1n(V_o/74)=5.72\ A^{-1}\ 1n(V_o/74)=59.5R\ 1n(V_o/74)$ where A

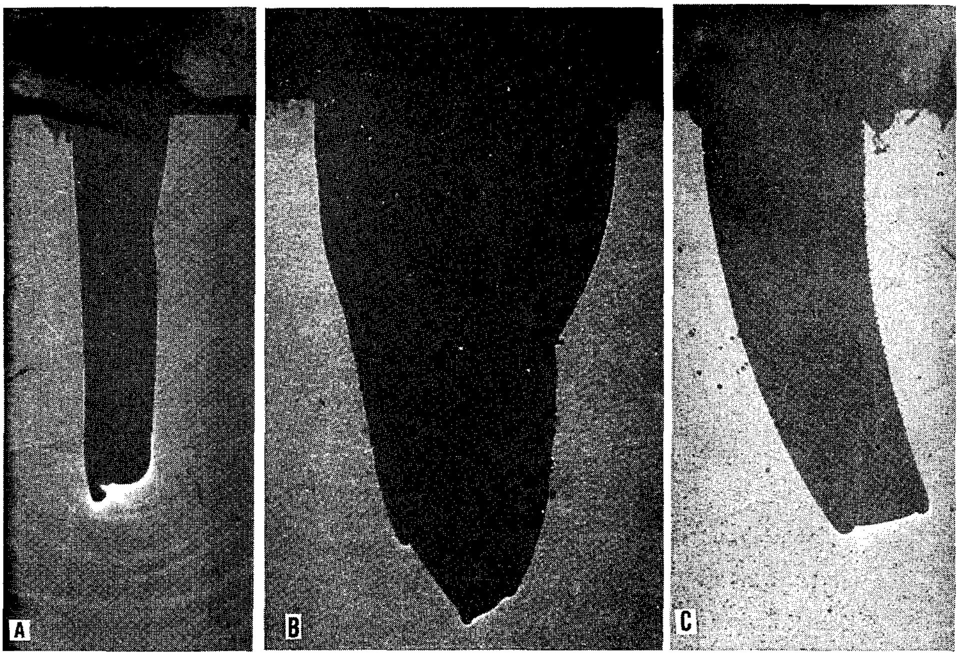

FIGURE 137.—Spark shadowgraphs of cavities produced by tumbling cylindrical slugs. The width of cavity indicates when they presented the largest projection area and hence delivered the most energy to the water. A. Shadowgraph (P 10) of cavity formed by a $\frac{3}{32}$- by $\frac{17}{32}$-inch steel cylinder with an entrance velocity between 2,000 and 3,000 f.p.s. It presented a small area just after entering but near the end of its flight seems to be turning rapidly. B. Shadowgraph (P 90) of cavity formed by a $\frac{5}{16}$- by $\frac{19}{32}$-inch aluminum cylinder. C. Shadowgraph (P 11) of cavity formed by a cylinder like the one shown in A.

is the projection area in cm.^{2}, α the retardation coefficient in cm.$^{-1}$, M the mass of the sphere in grams, V_o the impact velocity in meters per second, and R the radius of the sphere in centimeters. The penetration into gelatin gel of eight aluminum spheres having the same velocity but different radii, R, is shown in figure 139 where it is evident that spheres of larger radii penetrate a greater distance.

The penetration of small spheres into living soft tissue was determined by shooting into the thighs of deeply anesthetized dogs. It was assumed that the penetration law was the same as for gelatin gel and that only the constants which appear in the formula needed to be ascertained. The penetration formula for soft tissue was found to be:

$$P=\alpha-1\ 1n(V_o/84)=4.45A^{-1}M\ 1n(V_o/84=46.3R\ 1n(V_o/84).$$

Larger spheres having the same velocity undergo the greatest penetration. This is shown in the roentgenogram of figure 140 where several $\frac{2}{32}$- and $\frac{3}{32}$-

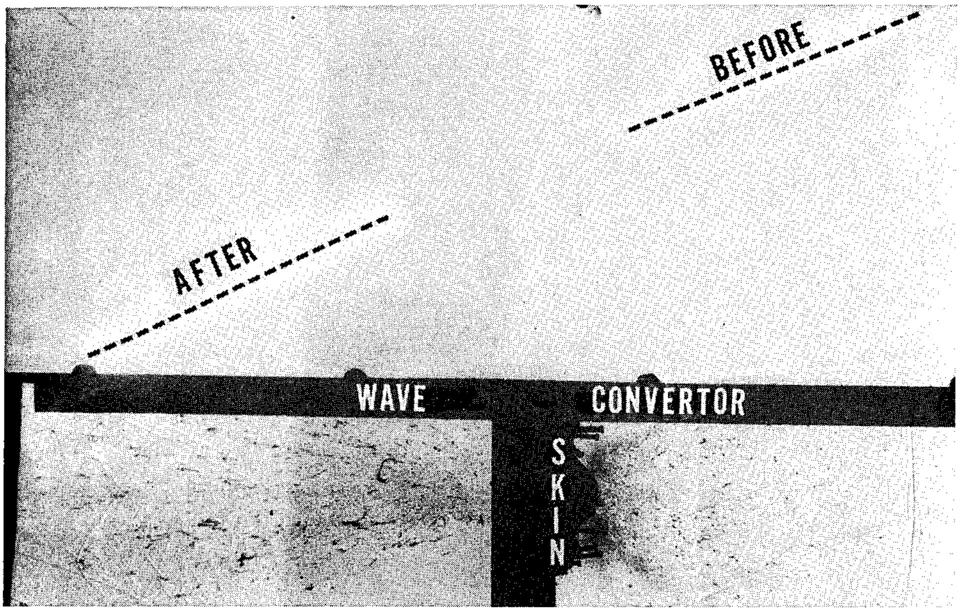

FIGURE 138.—Spark shadowgram (27 Mar. 1945) of several layers of skin just after perforation by a $\frac{3}{32}$-inch steel sphere. The missile moved from right to left. A plate with small holes converted the shock wave to a sound wave. The inclination of these waves to the missile path is used to measure the impact and residual velocities of the missile. Before impact, the velocity was 3,030 f.p.s. and after, 2,805 f.p.s. Note the debris flying back from entrance side and moving forward on exit side of skin.

inch steel spheres are shown embedded in the thigh of a dog. The spheres had nearly the same velocity, but the lighter $\frac{2}{32}$-inch spheres succeeded in going only about two-thirds the distance of the $\frac{3}{32}$-inch spheres. For spheres having exactly the same velocity, the penetration distance is inversely proportional to their radius. For spheres having the same radius, the penetration varies as the log of the impact velocity. This is illustrated in figure 141, where two $\frac{4}{32}$-inch spheres having impact velocities at 2,400 and 1,220 f.p.s. are shown imbedded in butcher meat. The faster ball is further advanced in the tissue.

When missiles other than spheres are considered, it is necessary to distinguish between a tumbling and a nontumbling missile. In a tumbling missile or fragment, the projection area may undergo considerable change in magnitude during flight, and the penetration of the same shaped fragment may vary considerably for different shots. For nontumbling fragments in soft tissue, it is supposed that the formula for penetration would be $P=6.67FMA^{-1}\ \ln(V_o/V_t)$, where F is a shape factor (one for a sphere) and V_t is a constant, which probably does not differ much from the one for a sphere having an equivalent projection area. In figure 142 is shown a fragment which has traveled broad-

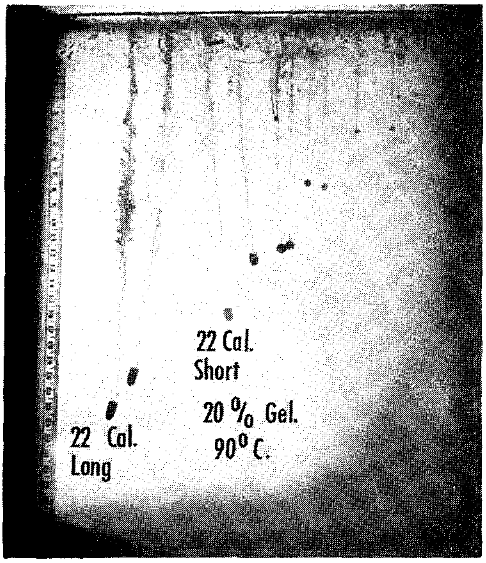

FIGURE 139.—Photograph of tank filled with 20 percent gelatin gel, showing the comparative penetration of varying size spheres and .22 caliber long and short bullets. The spheres were aluminum and had 8/32-,[1] 6/32-, 4/32-, and 3/32-inch diameters. Their impact velocity was about 2,800 f.p.s. The largest spheres penetrate the greatest distance. Scale in centimeters.

side and has been stopped after traversing only 6.1 cm. of a cat's abdomen. A sphere of the same mass, or the same fragment traveling end on, would have passed entirely through the abdomen without any difficulty. It is apparent that missiles other than spheres or spin stabilized bullets will have a considerable range of penetration distances, depending on their behavior during flight.

Spongy bone opposes the motion of a spherical missile with a force which acts in a different way from the one for soft tissues. In soft tissues, the force is proportional to the square of the velocity, while in bone the force is independent of the velocity. When the end of a beef femur was cut and spherical missiles shot into the spongy bone, it was found that the penetration was given by $P=8.15^{-5}R^2\ (V_o\text{–}200)^2$, where R is the radius of the sphere in inches, V_o the impact velocity in feet per second, and P the penetration in inches. The penetration is greatest for large spheres and increases with the square of the radius. The soft spongy bone of the femur stops missiles more readily than soft tissue. A 4/32-inch steel sphere traveling with a velocity of 2,000 f.p.s. in tissue will penetrate 23.3 cm., while the same sphere in bone will travel only 2.65 cm. before being stopped. It may be assumed that the penetration into bony tissues harder than those found in the femur will be correspondingly smaller. The spongy bone of the femur was used in these tests, because it afforded a large mass of fairly uniform bony material. Figure 143 shows three 4/32-inch spheres that have penetrated different distances into the end of a beef femur. The bone was sawed along a plane parallel to the axis to give a flat plane of entry. The sphere of highest velocity penetrated the greatest distance.

FIGURE 140.—Roentgenogram (No. 124) of the left thigh of a dog, showing the greater penetration of two 3/32-inch steel spheres in contrast to that of three 2/32-inch steel spheres. The spheres entered the lateral surface with a velocity of about 1,190 f.p.s. The pins indicate the entrance holes for two of the shots.

FIGURE 141.—Roentgenogram (No. 119) showing butcher meat penetrated by two 4/32-inch steel spheres of different velocities. The faster sphere (velocity 2,400 f.p.s) travels further than the slower one (velocity 1,220 f.p.s.). The spheres entered the meat at the left, and the nails at the bottom are 5 cm. apart.

CASUALTIES IN RELATION TO MISSILE MASS AND VELOCITY

An investigation was made to determine the mass and velocity relationship for a missile which is just capable of producing a casualty. The type of casualty chosen was that which would result when a certain vulnerable region in the body was pierced by the missile.

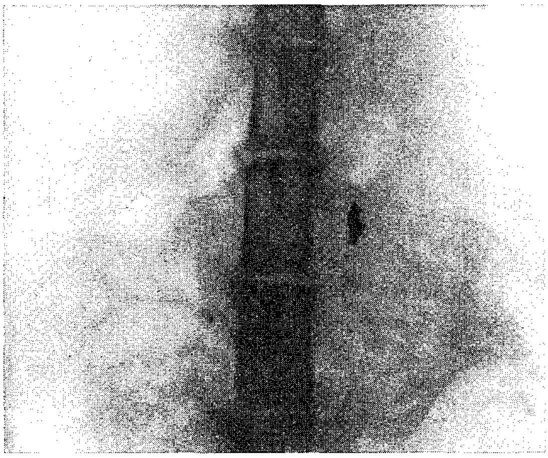

FIGURE 142.—Roentgenogram (No. 324) of a fragment (to right of vertebral column) which has penetrated about 6.1 cm. into the abdomen of a cat. It traveled with its largest projection area foremost (broadside). A sphere of the same mass would have passed completely through the abdomen. The fragment (from a 75 mm. shell) weighed 0.345 grams and entered from the left with an impact velocity of from 2,000 to 3,000 feet per second.

The total projection area of an erect man and the projection area of the vulnerable region in the body was measured by using anatomic drawings of body sections. The vulnerable regions included the organs, cavities, canals, and those nerves and blood vessels which have a diameter greater than 0.25 centimeter. The total projection area from the anterior aspect was 5.3 square feet, and the vulnerable projection area was 43 percent of this. Hands and feet were not included in the survey.

The thickness of the protective layer, made up of skin, bone, and soft tissue, was measured for each section of the vulnerable region. The average thickness of bone and soft tissue on the front and back of the body was 0.6 cm. and 3.3 cm., respectively. The vulnerable region was found to be better protected by soft tissue and bone from missiles coming from the rear than from those coming from directly in front.

The data on velocity losses in living cat muscles and in fresh human skin were used, in conjunction with penetration measurements on spongy beef bone, to calculate the minimum energy required to perforate the protective layer and pierce the vulnerable region. The calculation was made for 1/16-, 1/8-, and 1/4-inch steel spheres. These perforation energies for the 1/8-inch sphere varied from 2 to 216 ft.-lb. and depended on the composition and thickness of the protective layer immediately above the region being considered.

The probability that a hit by a given missile will result in a casualty was determined from the ratio of vulnerable projection area to total projection area, where the vulnerable projection area is a projection of those vulnerable regions which the missile is capable of piercing. This probability for any one missile was observed to rise rapidly with the missile's energy and velocity as soon as the threshold energy and velocity were attained. After passing an optimum energy, the probability of wounding increased at a smaller rate until a maximum was reached. This optimum energy was chosen as an index of the energy required of the missile in order to produce the type wound being

considered. The average optimum energy for $\frac{2}{32}$-, $\frac{4}{32}$-, and $\frac{8}{32}$-inch steel spheres, when calculated for missiles striking a man from directly in front or directly behind, was 15 foot-pounds. The average probability of wounding which this optimum energy gave was 60 percent of the maximum possible probability or was 0.25 in absolute units.

It was pointed out that the relationship between the mass and velocity of all missiles which produce a casualty of a given type depends on two factors: (1) The severity of the wound which causes this casualty, and (2) the probability that a hit on the body will produce such a wound. In the present analysis, it has been assumed that there is a large group of wounds which have the same severity and the probability of the occurrence of such wounds has been evaluated; the resulting relationship between the mass and velocity which was evaluated was too complex to present in any other way except pictorially.

The mass-velocity data showed that the energy necessary to wound a man increases as the mass of the missile is increased. This is true for the optimum energies and for those energies which give probabilities of wounding equal to 25, 50, and 75 percent of the maximum probability. This increase in energy with mass is shown to be generally true for any analysis in which penetration plays the predominant role.

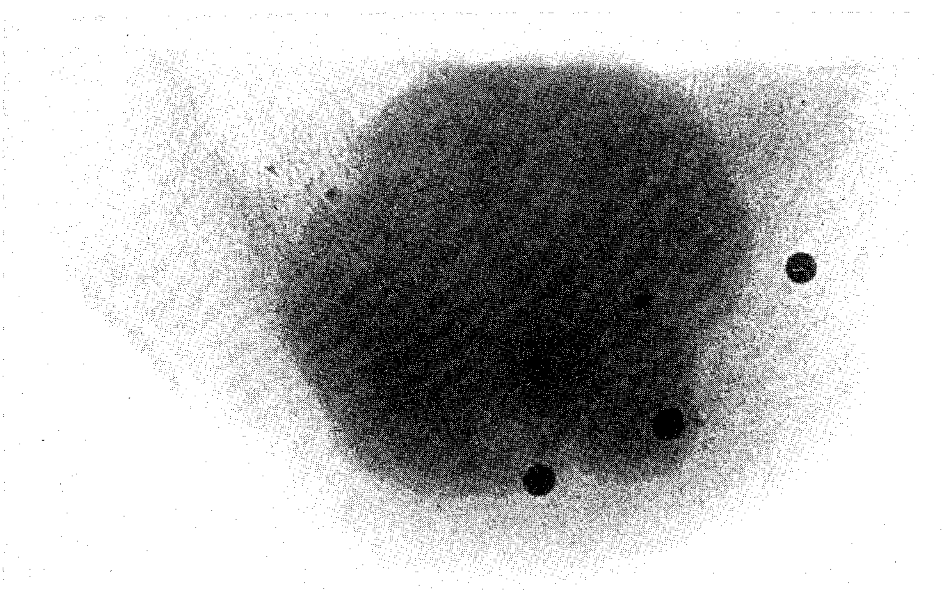

FIGURE 143.—Roentgenogram (31 Jan. 1945) showing $\frac{4}{32}$-inch steel spheres that have penetrated various depths into the spongy end of a beef femur. The impact velocities of these spheres were 1,670, 2,790, and 3,110 f.p.s., the fastest one having penetrated the greatest distance. The spheres entered the upper flat surface. The shaft of the bone is represented in cross section by the dark circular area.

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CHAPTER IV

Casualty Survey—New Georgia and Burma Campaigns

James E. T. Hopkins, M.D.

NEW GEORGIA CAMPAIGN

1ST BATTALION, 148TH INFANTRY, 37TH DIVISION

The material in this chapter is based on an attempt to survey and analyze the circumstances related to the production of battle casualties in three infantry battalions in combat, as follows:

The 1st Battalion, 148th Infantry, 37th Division, in the New Georgia campaign.

The 1st and 3d Battalions, 5307th Composite Unit (Provisional), in the Burma campaign.[1]

Materials and Methods

The same method of collecting data was followed in the New Georgia and Burma campaigns. Information on the circumstances in which the casualties occurred was obtained by questioning the surviving casualties; their friends and the friends of those killed in action; platoon leaders; company commanders; and medical officers. It should be emphasized that both the surviving casualties and those questioned concerning them and concerning the casualties killed in action were usually known to the writer of this chapter: in this type of warfare, officers and men lived in close association with each other. The opinions expressed are the writer's own, and many of them are no more than presumptions, especially as they concern comments that are strictly military.

[1] The author of this chapter, Dr. James E. T. Hopkins, a captain in the U. S. Army Medical Corps during World War II, served for 18 days of combat on New Georgia Island in 1943 as assistant battalion surgeon with the 1st Battalion, 148th Infantry, 37th Division. He also served as combat team surgeon and later as battalion surgeon for the 3d Battalion of the 5307th Composite Unit (Provisional) in Burma in 1944 ("Merrill's Marauders").

After only a few days of combat experience, Captain Hopkins was deeply impressed by the many casualties among U.S. troops which apparently resulted from carelessness. He was also impressed by the fact that a considerable number of casualties killed in action died from head and chest wounds in which the missiles entered from the front or from the side of the body. These observations led him to consider seriously the possibility of the use of body armor for the protection of vital areas of the body (p. 275).

During his time in combat, therefore, Captain Hopkins collected all possible data on combat casualties in order to demonstrate how combat losses could be reduced. The results of his studies were compiled with the help and encouragement of Col. (later Brig. Gen.) George R. Callender, MC, of the U.S. Army Medical Center and Chairman of the Missile Casualties (Wound Ballistics) Committee; Brig. Gen. Albert G. Love, of the Historical Division, Office of the Surgeon General; and Col. Michael E. DeBakey, MC, of the Surgical Consultants Division of the same office.—J. C. B.

On the other hand, all of the opinions expressed are based on a genuine effort to secure the precise facts. The writer secured much information on the battlefield, where he often acted as an aidman, and from close association with company commanders during actual fighting and with others in a position to know the facts.

The following data were obtained whenever this was possible:

1. The name of the casualty, with his rank, serial number, and unit.
2. The type of action; the type of terrain with available cover, and the duty of the casualty.
3. The weather conditions and the time of day.
4. The anatomic location of the wound and the degree of severity.
5. The type of causative agent and the approximate range.
6. The treatment received.
7. The classification of the casualty as to type and eventual disposition.
8. The classification of the casualty as to the possible avoidability of his injury. That is, an attempt was made to determine whether the injury might have been avoided by a more appropriate order from his officer, or by a better planned action on his own part, or for any other reason.

From the standpoint of type of casualty and eventual disposition, the following classification was used:

1. KIA (killed in action).—Those found dead or who died up to 30 minutes after being found.
2. DOW (died of wounds).—Those wounded casualties who reached a medical installation and survived more than 30 minutes and those who received treatment from a medical officer before death.
3. WIA (wounded in action).—Casualties wounded in action in New Georgia and in Burma were classified into four categories:

a.—Those returned to duty from the battalion aid station. Because of the terrain in New Georgia and the tactical nature of fighting in the jungle, wounded men were often retained in, and sent back to duty from, the battalion aid station, who, under more favorable circumstances, would have been evacuated for treatment. This was also true in the Burma campaign.

b.—Those returned to duty from a medical facility, within 1 month of wounding.[2] In New Georgia, there were no field, portable, or evacuation hospitals and no surgical teams, and the chain of evacuation was from the battalion aid station, usually through a collecting company, to a station hospital, in which urgent surgery was performed.

In Burma, during the first half of the campaign, casualties were evacuated by Piper Cub to the 20th General Hospital for initial wound surgery, which they frequently did not receive for 24 hours. During the second half of the campaign, the 42d Portable Hospital was flown in and operated in close proximity to the battalion aid station. After emergency treatment, the majority of these men were evacuated to the 20th General Hospital. Smaller numbers were evacuated to the 14th Evacuation Hospital and the 111th Station Hospital.

[2] For convenience of discussion hereafter termed "first echelon hospital."

c.—Those returned to duty from a medical facility within 4 months of wounding.[3] On New Georgia, those men who did not require urgent surgery or who, for various reasons, were not operated on in a first echelon hospital, were evacuated by LST's to a station hospital in Guadalcanal, which they usually reached within 24 to 36 hours. Some casualties were also evacuated to the station hospital in New Caledonia. The nearest general hospital was in the Fiji Islands.

d.—Those evacuated to the United States, after spending more than 4 months in hospital.

Geography and Climate

The New Georgia group of islands, which lie approximately 250 miles northwest of Guadalcanal, are chiefly made up of coral except for Kolombangara and Rendova, which are of volcanic origin. These islands, which are not so rugged and mountainous as the islands of the Guadalcanal group, are covered with thick jungle made up of large trees; tall, leafy jungle plants; and tangled vines and roots. Although the jungle growth is thick, it offers little actual obstruction for even men or machines. In many instances, bulldozers were able to weave around the larger trees and advance as much as a mile a day through the growth.

The casualties included in this study all took place on New Georgia Island between 18 July and 5 August 1943, inclusive. Even though this is a coral island, many areas are extremely marshy, and in the section about the Munda airfield very little coral is visible. The majority of the foxholes were dug in the red clay which made up the topsoil covering the coral.

During the period of combat, the climate was very mild, with temperatures ranging from 70° to 90° F. The humidity was very high, but rainfall was minimal.

Military Operation and Forces Involved

Military operation.—The New Georgia campaign, a combined military operation, had as its main objective seizure of the Munda airfield and driving the Japanese from New Georgia and the surrounding islands. The operation was started on 30 June 1943 and completed by 22 September 1943, with the occupation by U.S. troops of all important islands in the New Georgia group.

Elements of the 172d and 169th Infantry Regiments of the 43d Division landed on New Georgia Island at Zanana Beach between 2 and 6 July to proceed to a line of departure on the Barike River. After considerable fighting, with heavy casualties, these two regiments drove west on the Munda trail and established a new beachhead at Liana, at which the 103d Infantry of the 43d Division was landed.

On 11 July 1943, these three regiments started an attack on the Japanese defensive position along the coastal strip. On 18 July, the 148th and 145th

[3] For convenience of discussion hereafter termed "second echelon hospital."

Infantry Regiments of the 37th Division landed at the Zanana and Liana beachheads. These regiments, together with the 161st Infantry of the 25th Division, started a coordinated attack on 25 July which ended in the seizure of the Munda airfield on 5 August 1943.

Forces involved.—It is difficult to make an accurate estimate of the number of men engaged in the campaign on New Georgia because of the many types of military units involved and the various locations of the islands on which the fighting took place. For the first 17 days of the campaign, no more than 8,000 infantrymen fought on New Georgia. By 25 July, this force had increased to 15,000 men. The total strength of all U.S. forces involved in the New Georgia campaign was approximately 35,000. Table 26 lists the total U.S. casualties of the New Georgia campaign; 95 percent of these losses occurred during the first 5 weeks.

Southwest sector.—Between 18 July and 5 August 1943, the period covered by this survey of casualties in the 1st Battalion, the 148th Infantry operated in the southwest sector of New Georgia Island with this battalion, the 2d Battalion, and a regimental headquarters. The 3d Battalion operated separately with a force of Marines on the north side of the island.

TABLE 26.—*Distribution of 4,994 casualties of the New Georgia campaign, 30 June–22 September 1943, by category and division*

Category	Total casualties		25th Division		37th Division		43d Division		Other
	Officers	Enlisted men	Officers	Enlisted men	Officers	Enlisted men	Officers	Enlisted men	Enlisted men
Killed in action	48	924	11	120	11	179	26	436	189
Wounded in action	169	3, 704	35	515	47	840	87	1, 855	494
Died of wounds	7	115	1	9	------	36	6	70	------
Missing in action	2	21	------	1	------	5	2	15	------
Accidental deaths	------	4	------	2	------	2	------	------	------
Total	226	4, 768	47	647	58	1, 062	121	2, 376	683

The 1st and 2d Battalions of this regiment arrived at Zanana Beach on 18 July. The 2d Battalion proceeded to relieve the 43d Division command post, which had been surrounded, and to open the supply route to the 169th and 172d Infantry Regiments of the 43d Division. The 1st Battalion, which arrived early in the morning, after a few minor contacts with the Japanese, succeeded in advancing within 1 mile of the Barike River along the Munda trail.

At 1100 hours on 19 July, when the battalion was advancing along this trail, it came under automatic weapons fire at the Barike River; several men were killed and several wounded. The river was not crossed until 20 July,

when the battalion succeeded in advancing to a parachute drop where the 169th Infantry was relieved. A few casualties occurred during the day from enemy automatic weapons fire and from friendly artillery fire.

At 0600 hours on 25 July, the battalion attacked from a line of departure in front of O'Brien Hill on a 270° azimuth, which it was to follow until the end of the campaign for the Munda airfield.

The 37th Division had been assigned a sector north of the north flank of the 43d Division and had been given the primary mission of securing the high ground commanding the Munda airfield. From right to left toward the beach front, U.S. forces were disposed as follows:

1st and 2d Battalions, 148th Infantry Regiment.

The 161st Infantry Regiment.

2 battalions of the 145th Infantry Regiment.

The 176th Infantry Regiment.

The 103d Infantry Regiment.

This general alinement of regiments was to be maintained until the fall of the Munda airfield on 5 August 1943.

By the afternoon of 27 July, the two battalions of the 148th Infantry had advanced slightly beyond and to the right of O'Brien Hill and had begun to set up a supply dump in this area. There was considerable patrol activity during this time. On the following day, after losing five men in an ambush, the 1st and 2d Battalions advanced 1,000 yards on the 270° azimuth to a point overlooking Biblo Hill. Very little opposition was offered by the enemy.

One company was left to protect the supply dump, but on 29 July it was surrounded by a superior Japanese force and all communications were severed. Following this action, the two battalions were forced to withdraw. The 2d Battalion, minus Companies G and E, withdrew to the 37th Division area by traveling single file through the jungle.

The 1st Battalion, together with Companies G and E of the 2d Battalion, fought the Japanese along the trail and about the supply dump until the morning of 1 August, when they routed the enemy forces and again established contact with the 161st Infantry, which had been advancing westward on their left flank.

The action just described resulted in a large proportion of the casualties sustained by the 148th Infantry during this campaign. For 4 days, the 1st Battalion had no means of evacuating its wounded.

On 1 August, the regiment again began its advance to the right of the 161st Infantry. During the next 4 days, it continued in a coordinated attack with the other regiment until it finally reached the beach approximately 1,000 yards north of the Munda airfield.

During this operation, the majority of U.S. casualties resulted from automatic weapons fire, though a considerable number were due to friendly artillery and mortar fire. There was no enemy aerial activity during the later stages of this campaign.

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Casualties of 1st Battalion, 148th Infantry

U.S. troops in the southwest sector of New Georgia Island never exceeded 18,000 infantrymen. It was estimated that there were never more than 6,000 Japanese troops involved in the fighting in this sector, which was the heaviest in the campaign.

Table 27 lists the casualties incurred by the 1st Battalion, 148th Infantry, during the 18 days of this survey. Approximately 2,000 enemy dead were counted during the period between 3 July and 5 August. During the 18 days the 1st Battalion was in combat, it was estimated that they killed between 300 and 400 Japanese with small arms and mortar fire and that artillery fire directed by officers of the rifle companies accounted for an additional 100 to 200 Japanese dead.

TABLE 27.—*Distribution of 181 casualties, 1st Battalion, 148th Infantry, 18 July–5 August 1943, by category*

Category	Casualties	
	Number	Percent
Killed in action	35	19. 3
Wounded in action:		
Died of wounds	11	6. 1
Survived wounds	135	74. 6
Total	146	80. 7
Grand total	181	100. 0

Hospitalization and evacuation.—When the 1st Battalion, 148th Infantry, 37th Division, arrived at Zanana Beach, New Georgia Island, on 18 July 1943, one collecting company (Company B, 118th Medical Battalion) was serving the elements of the 43d Division about the Munda area. For the first 5 days of the campaign, only this company served the 1st Battalion. On 22 July, the 112th Clearing Company moved to Liana Beach about 1 mile behind the 1st Battalion sector, but its collecting companies did not reach the battalion aid station until 3 August, the 17th day of combat. In the meantime, some medical care was provided by a collecting company from the 25th Division.

While no attempt will be made to discuss routes of evacuation and types of medical care for units involved in the campaign other than the 1st Battalion, 148th Regiment, it might be added that according to a report from the Office of the Surgeon, South Pacific Area, entitled "Medical Service, New Georgia Campaign," the medical and surgical care provided during the greater part of the New Georgia campaign was deficient in many respects and medical facilities

from battalion aid levels through the hospital echelon were also often inadequate.

Most of the 1st Battalion casualties were evacuated on regimental supply trucks or ambulance jeeps (fig. 144). During the first 5 days of combat, they were taken from Zanana Beach to Guadalcanal by LST's, a distance of 200 miles which required from 20 to 24 hours' travel time. As a rule, no treatment other than first aid was provided before the trip. En route, medical care for the 100 to 200 casualties usually carried on each ship was provided by one Navy medical officer.

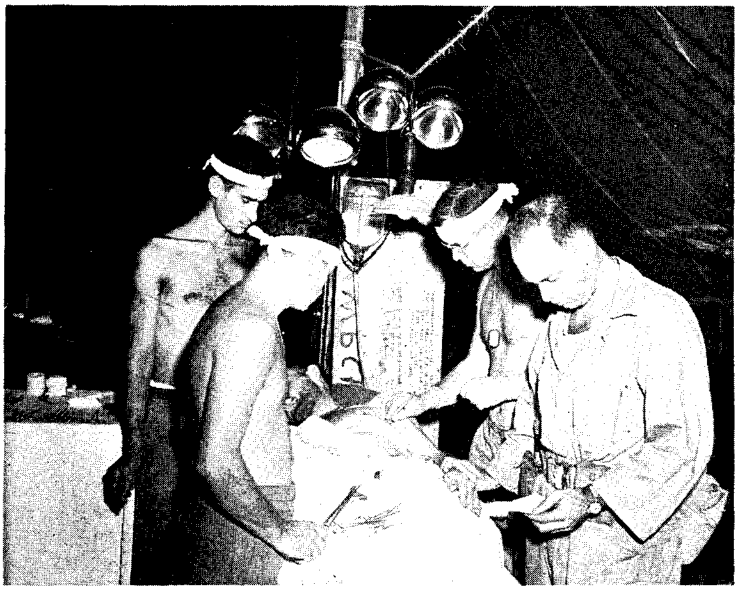
SC 180136

FIGURE 144.—Medical aidmen carrying wounded man to ambulance jeep.

After the fifth day of combat, casualties were evacuated through the 112th Clearing Company, and in many instances surgery was provided at this level (fig. 145). Because of the 24-hour evacuation policy, however, many casualties who had been treated inadequately took the long trip to Guadalcanal.

It was not until 28 July that the 17th Field Hospital was set up on Kokorana Island, 5 miles from the Liana beachhead. With the facilities thus provided, the wounded from the 1st Battalion had the benefit of hospitalization about 3 miles distant by land routes and about 5 miles by water evacuation (fig. 146).

During the 5-day period between 28 July and 1 August, all supply lines were cut, as already mentioned, and casualties from the 1st Battalion and from Companies G and E of the 2d Battalion could not be evacuated from the



SC 186540

FIGURE 145.—Members of 37th Division Clearing Company completing a surgical procedure, New Georgia Island.

SC 180533

FIGURE 146.—Wounded soldiers lying in vessel, awaiting transportation to the 17th Field Hospital.

battalion area; a large number of them therefore received no surgical treatment for several days.

Details of the 181 casualties sustained on New Georgia Island, as they were related to the various tactical situations, appear in appendix A (p. 769).

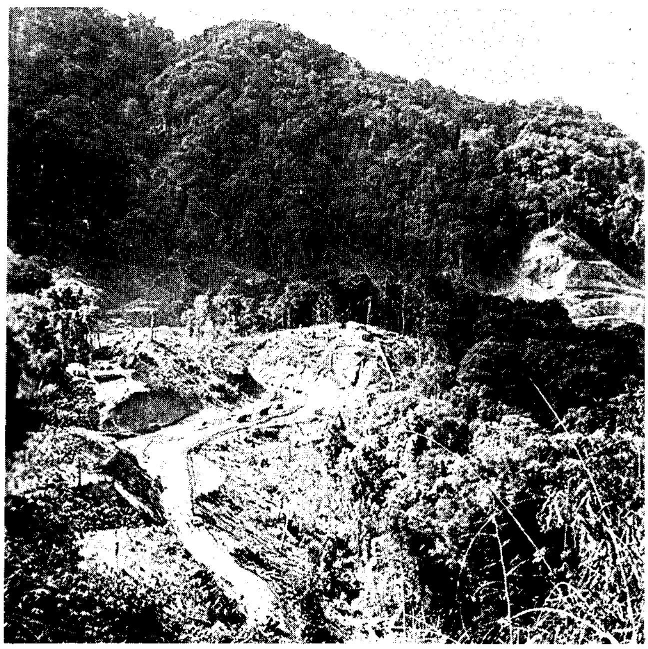
BURMA CAMPAIGN

1ST AND 3D BATTALIONS, 5307TH COMPOSITE UNIT (PROVISIONAL)

Geography and Climate

Northern Burma is separated from India and China by the high mountain ranges which make up the foothills of the Himalayas, some of which reach an altitude of 20,000 feet. As in all of northern Burma, the jungle is very heavy but is usually not impenetrable. The terrain is the main factor that makes it difficult to pass through the jungle growth.

The unit reached Burma after a march up the Ledo Road (fig. 147) and through the Pangsau Pass of the Kumon Range at 2,400 feet. They then passed into the Hukawng Valley, a very narrow valley bordered by very hilly, rugged, mountainous terrain. Much of the operation took place on the razorback ridges of the hills on the eastern border of the valley.



SC 189289

FIGURE 147.—View of the Ledo Road.

Practically all of the unit's operations in this area, as well as in the Mogaung and Myitkyina Valleys, were confined to the century-old native and game trails that are seen throughout all of northern Burma. The Hukawng Valley is extremely flat and is covered in some areas with dense jungle growth and in others with elephant grass. The average altitude is approximately 500 feet. Numerous Kachin villages, with a few native inhabitants, were repeatedly encountered throughout this area. The Mogaung Valley was approached through difficult terrain over the Ywangabum Mountains, along the course of the Tanai Hka River.

After its operations in this area, the unit retraced its route for perhaps 50 miles and passed over the 6,500-foot Jaupadu Bum Mountains that separate the Mogaung Valley from the Myitkyina Valley. This terrain was perhaps the most rugged encountered during the North Burma campaign; in some places, 1-mile stretches of the overgrown trails had a rise of 3,000 feet.

During February and March 1944, the days were very hot, and the temperature averaged about 80° F. The nights, however, were cool, and additional clothing was required. There was a minimum amount of rainfall during the entire campaign.

April was very warm during the day, and there was practically no rainfall. May was hot and humid, with almost daily showers. This was the beginning of the monsoon season, which continued until the end of October, but it did not materially affect operations as the majority of the troops had left the area by the end of June.

Organization of 5307th Composite Unit (Provisional)

In September 1943, 650 men and officers, all volunteers, congregated in New Caledonia to form a special infantry battalion. They had been selected from the 37th, 43d, 25th, and Americal Divisions. Later, 250 additional men and officers arrived, from the 32d and 41st Divisions and from the 98th Pack Artillery, from Australia. Most of these men had been overseas for more than a year and had seen action in the South Pacific or Southwest Pacific Areas.

These men made up the 3d Battalion of what was to become the 5307th Composite Unit (Provisional). They traveled to India on a transport with a battalion from the United States, which was to become the 1st Battalion of this Unit, and a battalion from the Carribean area which was to become the 2d Battalion.

These three battalions, organized as an infantry regiment, trained in India from November 1943 to January 1944. During this time, there were many transfers of men within the battalions, and about 150 replacements arrived from casual units. The 31st Quartermaster Pack Troop was also absorbed by the regiment. On 1 January 1944, the three battalions were formally activated as the 5307th Composite Unit (Provisional).

After ship and train travel, the entire regiment arrived at Ledo, Assam,

during the first week of February 1944. Its primary mission was to spearhead the Chinese movement into North Burma.

After a march of 125 miles up the Ledo Road, the regiment left the Chinese in the vicinity of Nyenbien, on the Chindwin, in the third week of January and set out on a campaign which was to carry them on foot between 700 and 1,000 miles over the mountainous and jungle terrain of northern Burma. They were to aid the Chinese in the occupation of the Hukawng, Mogaung, and Myitkyina Valleys. Their mission was climaxed by the capture of the Myitkyina airfield on 17 May 1944.

Early in June 1944, most of the 1st Battalion were evacuated to various hospitals. The few who were not were reinforced with 300 to 400 men who had been released from hospitals in late May and early June. The reorganized battalion fought in the attack on Myitkyina during the latter part of June, during July, and during the first 2 weeks of August. The casualties sustained after 8 June are not included in this survey.

Military Operation and Forces Involved

During the second week of February 1944, the three infantry battalions which made up "Merrill's Marauders" entered northern Burma. After making a wide flanking movement to the left of the Hukawng Valley, they arrived in the vicinity of Walawbum during the first week of March. The numerous skirmishes and several engagements which took place resulted in complete success for the U.S. troops, and the operation enabled the Chinese to occupy the entire Hukawng Valley. Shortly after their arrival near Walawbum during the first week of March, the regiment was relieved by Chinese troops.

During the next 3 weeks, the 1st Battalion, reinforced by a regiment of Chinese, marched across the Aipawn Bum Mountains to engage the Japanese at Shaduzup in the northern sector of the Mogaung Valley. This operation, which was also very successful, enabled the Chinese divisions to enter the upper part of the Mogaung Valley, after passing down the Japanese-built road through the Jamba Bum Pass.

Meantime, the 2d and 3d Battalions of the regiments crossed the Wangabum Mountains to the east, where they engaged the Japanese at Inkangatawng, about 50 miles distant and 20 miles above Kamaing. The success of this operation enabled the Chinese troops to advance rapidly down the Mogaung Road toward Kamaing, but because these troops failed to fulfill their assigned mission, the 2d and 3d Battalions were forced to withdraw to the mountains in the vicinity of Nhpum Ga, where one battalion was surrounded. The other, with the aid of air-dropped pack artillery (fig. 148), engaged the Japanese for 9 days in a major battle to relieve the encircled troops.

After the Japanese had been routed, in the third week of April, the three battalions of the unit assembled at the base of the Jaupadu Bum Mountains for the Myitkyina campaign. For this campaign, two forces were organized: (1) The 3d Battalion with the 88th Infantry Regiment (Chinese) and (2) the

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FIGURE 148.—U.S. troops and Kachin natives watching a parachute supply drop.

1st Battalion with the 150th Infantry Regiment (Chinese). The 2d Battalion was held in regimental reserve.

While these troops were passing through the Myitkyina Valley, two major battles developed, both of which eventually ended in complete success for the U.S. forces. The Myitkyina airfield was captured by the 1st Battalion and the attached Chinese regiment on 17 May 1944. Shortly afterward, some 4,000 engineer and infantry troops were flown in.

For the greater part of the original 5307th Composite Unit (Provisional), the campaign in the Myitkyina area lasted another 3 weeks. The town itself did not fall for 2½ months; then it was taken by Chinese forces with the remnants of less than a battalion of the original unit.

Forces involved.—It is estimated (table 28) that a total of 8,700 U.S. troops were involved in the Myitkyina campaign. Official, reliable figures are not available for the size of the enemy forces or casualties, nor are reliable figures available for Chinese casualties.

Casualties, 15 February–8 June 1944

Table 28, in addition to listing the numbers of U.S. troops involved, and the estimated numbers of Japanese and Chinese troops involved, in the North Burma campaign during the study period from 15 February to June 1944, also lists the casualties of the three forces. Certain of the 2d Battalion engagements are not included in this table; their casualties would total about 40 KIA and about 200 WIA. Also excluded from the table are the several hundred casualties, KIA and WIA, sustained by the two infantry and two

TABLE 28.—*Estimated number of troops involved and casualties sustained, Burma campaign, 15 February–8 June 1944*

Locality	Troops involved			Casualties sustained		
	United States	Chinese	Japanese	United States, killed in action	Japanese, killed in action	United States, wounded in action
Walawbum	2, 700	--------	1, 000	5	850	28
Shaduzup	800	3, 000	1, 000	8	600	23
Inkangahtaung	1, 200	--------	1, 000	2	350	3
Nhpun Ga, Auche, Warong Poakum	1, 600	--------	1, 000	22	600	67
Riptong	700	3, 000	200	1	185	4
Tingkrukawng	700	2, 900	400	6	350	15
Myitkyina:						
1st Battalion	500	--------	50–200	3	(1)	9
3d Battalion	500	--------	200–400	6	85	15
Total	8, 700	8, 900	4, 850–5, 200	53	3, 020	164

1 Undetermined.

engineer battalions flown into Myitkyina after the airfield was captured by U.S. troops.

While it was seldom possible to examine or count enemy dead, it is believed that about 3,000 Japanese were killed in North Burma. During the same period, including the 40 casualties KIA from the 2d Battalion, almost 100 U.S. troops were killed.

Evacuation and hospitalization.—The three battalions of the 5307th Composite Unit (Provisional) operated along separate trails for the greater part of the campaign in Burma. Evacuation of the wounded was frequently not possible for periods of a week or more, but the majority were evacuated between a few hours to 10 days after wounding. During most of the major engagements, landing strips were built on the rice paddies of the native villages, and the wounded were evacuated by aircraft. A few casualties were put in the care of Kachins (fig. 149), who evacuated them by litter or by elephant transport.

After the capture of the Myitkyina airfield (fig. 150), casualties were evacuated by C–46's and C–47's to hospitals in the Ledo area; namely, the 20th General Hospital, the 14th Evacuation Hospital, and the 111th Station Hospital. During the first 3 months of the campaign, the patients were deposited in various collecting and clearing companies along the Ledo Road, behind the advancing Chinese troops. In many instances, they did not reach the 20th General Hospital until several days after they had been wounded.

For the first 3 weeks of March, during the Shaduzup campaign, the 1st Battalion had the services of a surgical team supplied by the Seagrave Unit.

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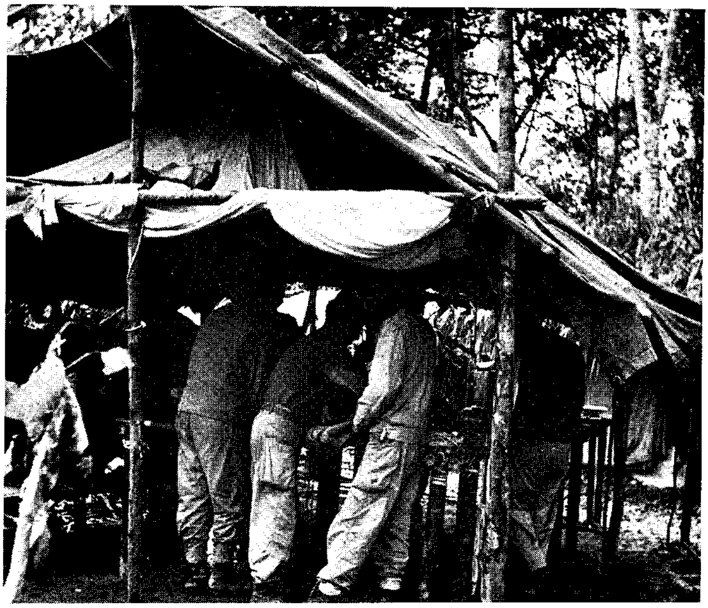
FIGURE 149.—Kachins from a friendly native village leading men of the 5307th Composite Unit (Provisional) through the jungle.

U.S. Army photo

FIGURE 150.—Wounded soldiers awaiting evacuation, Myitkyina airfield.

After they had been treated, these casualties were picked up by a platoon from a collecting company of the 13th Medical Battalion.

During the first 3 weeks of May, the 1st and 3d Battalions had the support of the 42d Surgical Portable Hospital and the Seagrave Portable Hospital. As a result, the majority of their casualties received surgery within a few minutes (fig. 151) to a few hours after wounding.



SC 189393

FIGURE 151.—Operating room of surgical team in field hospital.

During the march up the Ledo Road, about 70 litter patients (fig. 152) were carried for as much as 10 miles to an airstrip 40 miles north of Myitkyina.

Aside from the variable, and sometimes inadequate, facilities for their evacuation, the men of the 5307th Composite Unit (Provisional) received excellent surgical care.

Casualties sustained.—Table 29 lists the casualties of the 1st and 3d Battalions, 5307th Composite Unit (Provisional), during the Burma campaign for the period 15 February to 8 June 1944, inclusive. Detailed reports of these casualties in relation to the various tactical situations appear in appendix B for the 1st Battalion (cases 1–61, p. 783) and in appendix C for the 3d Battalion (cases 1–151, p. 789). Table 30 is a compilation of tables 27 and 29, comparing the casualties of the survey periods in the New Georgia and Burma campaigns.

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FIGURE 152.—Litter bearers carrying wounded Chinese soldier to an ambulance pickup point.

TABLE 29.—*Distribution of 212 casualties, 1st and 3d Battalions, Burma campaign, February-June 1944, by category*

Category	1st Battalion 5 Mar.-8 June	3d Battalion 28 Feb.-21 May	Total casualties	
			Number	Percent
Killed in action	7	24	31	14. 6
Wounded in action:				
Died of wounds	8	17	25	11. 8
Survived wounds	46	110	156	73. 6
Total	54	127	181	85. 4
Grand total	61	151	212	100. 0

TABLE 30.—*Distribution of 393 casualties, 1st Battalion, New Georgia Island, and 1st and 3d Battalions, 5307th Composite Unit (Provisional), Burma, by category and survey period*

Category	1st Battalion, New Georgia, 18 July–5 August 1943	1st and 3d Battalions, Burma, February–June 1944	Total casualties	
			Number	Percent
Killed in action	35	31	66	16. 8
Wounded in action:				
Died of wounds	11	25	36	9. 2
Survived wounds	135	156	291	74. 0
Total	146	181	327	83. 2
Grand total	181	212	393	100. 0

ANALYSIS OF CASUALTIES

Basic Data

The units involved in the survey described in the preceding pages included:

The 1st Battalion, 148th Infantry, 37th Division, on New Georgia Island, 18 July–5 August 1943, inclusive.

The 1st and 3d Battalions, 5307th Composite Unit (Provisional), in Burma, 15 February–8 June 1944, inclusive.

In the preceding pages, in which each of these units was considered separately, the background for the New Georgia and the Burma campaigns was described, including the geography; the climate; the general order of battle, including the troops involved; and the evacuation and hospitalization setup. In the appendixes for each of these campaigns, there are provided further details of the tactical situation as related to the number and location of the wounds sustained and the disposition of the WIA casualties. The military situation has been clarified by the arrangement of all actions into tactical situations, and each individual injury (injuries) has been described in such a way that it is possible to demonstrate what part each casualty played in the particular tactical situation. Injuries that seemed preventable are frankly indicated.

For ease of reference, the combined figures for the two campaigns are brought together here. They consist of:

369 casualties, exclusive of 23 casualties carded for record only (CRO) and 1 KIA casualty not sustained in combat. These 24 casualties are not considered further in most of the discussion.

101 fatal wounds, made up of 65 KIA casualties and 36 DOW casualties.

268 survivors, whose wounds were distributed as follows:

42 head
31 chest
14 abdomen
143 extremities, broken down into:
62 wounds of upper extremities
81 wounds of lower extremities
38 multiple wounds.

Table 31 lists the total casualties sustained during the survey period, with their general disposition among the various categories. The analysis reveals the following facts:

1. The ratio of the total 393 casualties to the 102 total dead (KIA and DOW) was 3.9 : 1.

2. The ratio of the 291 survivors (WIA excluding DOW) to the 102 total dead (KIA and DOW) was 2.9 : 1.

TABLE 31.—*Distribution of 393 casualties, 1st Battalion, 148th Infantry, 37th Division, New Georgia Island, 18 July–4 August 1943, and 1st and 3d Battalions, 5307th Composite Unit (Provisional), Burma campaign, February–June 1944, by category*

Category	Casualties	
	Number	Percent
Dead:		
Killed in action	66	16. 8
Wounded-treated-died-later	36	9. 2
Total	102	26. 0
Living wounded:		
Returned to duty from:		
Aid post	74	18. 8
Hospital, first echelon	61	15. 5
Hospital, rear echelon	91	23. 2
Evacuated to United States	42	10. 7
Minor wounds, no record	23	5. 8
Total	291	74. 0
Grand total	393	100. 0

3. If the 23 casualties carded for record only are excluded from the analysis, the ratio of total wounded to true KIA was 4.7: 1. This is the more commonly used ratio. In this survey, it is undoubtedly related to the close proximity of the medical installations to the frontlines and to the fact that

a considerable number of casualties listed as DOW might well have been tabulated as KIA under other circumstances.

4. Among the total 393 casualties, 249 (63.3 percent) were returned to duty. If the 23 CRO casualties are excluded, 226 (57.5 percent) were returned to duty.

Anatomic Frequency

Table 32 lists the anatomic distribution (regional frequency) of wounds in the 369 battle casualties and table 33 the distribution among the 101 dead. The following comments seem warranted:

1. Wounds of the head and of the thorax accounted for the same proportion of deaths among the KIA and the DOW. Among the 32 casualties with head injuries were 23 KIA's and 5 DOW's with brain injuries and 2 KIA's and 2 DOW's with injuries to the face and neck.

2. The fact that more thoracic wounds were observed in this survey than in the Bougainville study (p. 318) is related to the greater proportion of patrol and offensive action in this study. All casualties who died from thoracic wounds had perforating injuries.

3. Although no KIA's are found among the abdominal injuries listed as such, some casualties tabulated under multiple injuries had abdominal wounds. Of the 25 casualties with abdominal wounds, 13 had visceral lesions, but only one was operated on. Three of the casualties listed in the multiple injuries group had laparotomies, but none survived. During the survey period, most casualties with abdominal wounds were not killed instantly but died of shock and hemorrhage before they could be operated on. Early, adequate surgery would have decreased considerably the number of DOW's in the New Georgia-Burma campaigns.

TABLE 32.—*Distribution of wounds in 369 battle casualties, by anatomic location (regional frequency)*[1]

Anatomic location	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [2]	Number	Percent [2]
Head	74	20. 1	32	43. 2	42	56. 8
Thorax	63	17. 1	32	50. 8	31	49. 2
Abdomen	25	6. 8	11	44. 0	14	56. 0
Extremities:						
Upper	63	17. 1	1	1. 6	62	98. 4
Lower	83	22. 4	2	2. 4	81	97. 6
Multiple	61	16. 5	23	37. 7	38	62. 3
Total	369	100. 0	101	27. 4	268	72. 6

[1] Twenty-three cases with very minor wounds and one nonbattle casualty excluded from total number of casualties.
[2] Percent for dichotomy, dead versus living, by each anatomic location and for total dead versus living.

TABLE 33.—*Distribution of wounds in 101 dead, by anatomic location*

Anatomic location	Total casualties		Killed in action		Died of wounds	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Head	32	31. 7	25	78. 1	7	21. 9
Thorax	32	31. 7	25	78. 1	7	21. 9
Abdomen	11	10. 9		. 0	11	100. 0
Extremities:						
Upper	1	1. 0		. 0	1	100. 0
Lower	2	2. 0		. 0	2	100. 0
Multiple	23	22. 7	15	65. 2	8	34. 8
Total	101	100. 0	65	64. 4	36	35. 6

[1] Percent for dichotomy, killed in action versus died of wounds, by each anatomic location and for total killed in action versus died of wounds.

Table 34 lists the regional frequency of wounds among the 268 casualties who survived their wounds. It is apparent in this survey, as it has been apparent in others, that wounds of the extremities predominate among the WIA and that this group sustained fewer wounds in the anatomic regions in which vital organs are located.

Table 34 also indicates the results of surgical skill in the management of wounds of the extremities. The lack of definitive care in these campaigns is shown by the fact that few casualties with serious abdominal wounds lived to be evacuated to the United States. A high proportion of those who survived to be evacuated had only flesh wounds in this critical area.

TABLE 34.—*Distribution of wounds in 268 living wounded, by anatomic location*

Anatomic location	Total casualties		Returned to duty		Evacuated to United States	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Head	42	15. 7	30	71. 4	12	28. 6
Thorax	31	11. 6	28	90. 3	3	9. 7
Abdomen	14	5. 2	13	92. 9	1	7. 1
Extremities:						
Upper	62	23. 1	56	90. 3	6	9. 7
Lower	81	30. 2	69	85. 2	12	14. 8
Multiple	38	14. 2	30	78. 9	8	21. 1
Total	268	100. 0	226	84. 3	42	15. 7

[1] Percent for dichotomy, duty versus evacuated to United States, by each anatomic location and for total duty versus evacuated to United States.

Distribution of Wounds in Relation to Projected Body Area

Missiles from a given weapon usually move in one direction toward a casualty. If the projected area of the body is completely exposed, it therefore offers a better measure for the study of probable hits than the area of the total unprotected body surface. The mean projected body area is obtained from projection in the standing, kneeling, and sitting positions.[4]

Table 35 presents a comparison of mean projected body areas with body areas hit. The wound distribution for the thorax exceeds the mean projected body area by 4.5 percent, while wounds of the head exceed it by 7.9 percent.

TABLE 35.—*Mean projected body area and wound distribution (dead and living, including multiple wounded) and type of weapon*

Anatomic location	Mean projected body area	Wound distribution	Rifle	Machine-gun	Mortar	Artillery	Grenade
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Head	12. 0	19. 9	21. 1	20. 3	20. 2	19. 4	18. 7
Thorax	16. 0	20. 5	22. 1	19. 5	21. 3	19. 4	20. 0
Abdomen	11. 0	9. 6	7. 4	12. 8	12. 8	5. 6	9. 3
Extremities:							
Upper	22. 0	21. 0	26. 2	20. 3	18. 1	16. 7	24. 0
Lower	39. 0	29. 0	23. 2	27. 1	27. 6	38. 9	28. 0
Total	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0

Distribution of Wounds in Relation to Disposition of Casualties

Table 36 presents a breakdown of the anatomic distribution of wounds in relation to the general disposition of wounded casualties who survived. Casualties with wounds of the extremities show a very low mortality rate, a high percentage of returns to duty, and a relatively high incidence of evacuation to the United States.

Table 37 presents the incidence of fractures of the extremities (62 upper, 81 lower) among surviving casualties. Of the 143 with wounds of the extremities, 31 (44.0 percent) had associated fractures. There were 15 fractures (24.2 percent) among the 62 wounds of the upper extremity and 16 (19.8 percent) among the 81 wounds of the lower extremities. Among the 42 casualties evacuated to the United States, 18 were returned because of fractures.

[4] Burns, B. D., and Zuckerman, S.: The Wounding Power of Small Bomb and Shell Fragments. R. C. No. 350 of the Research and Experiments Department of the Ministry of Home Security.

TABLE 36.—*Distribution of 369 battle casualties, by anatomic location of wounds (regional frequency) and by disposition*

Anatomic location	Regional frequency	Total casualties		Dead						Living wounded									
				Total		Killed in action		Died of wounds		Total		Returned to duty from aid post		Returned to duty from first echelon		Returned to duty from rear echelon		Evacuated to United States	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
	Percent																		
Head	20. 0	74	100. 0	32	43. 2	25	33. 7	7	9. 5	42	56. 8	16	21. 6	7	9. 5	7	9. 5	12	16. 2
Thorax	17. 1	63	100. 0	32	50. 8	25	39. 7	7	11. 1	31	49. 2	16	25. 4	6	9. 5	6	9. 5	3	4. 8
Abdomen	6. 8	25	100. 0	11	44. 0	----	. 0	11	44. 0	14	56. 0	5	20. 0	1	4. 0	7	28. 0	1	4. 0
Extremities:																			
Upper	17. 1	63	100. 0	1	1. 6	----	. 0	1	1. 6	62	98. 4	15	23. 8	19	30. 2	22	34. 9	6	9. 5
Lower	22. 5	83	100. 0	2	2. 4	----	. 0	2	2. 4	81	97. 6	17	20. 5	15	18. 1	37	44. 6	12	14. 4
Multiple	16. 5	61	100. 0	23	37. 7	15	24. 6	8	13. 1	38	62. 3	5	8. 2	13	21. 3	12	19. 7	8	13. 1
Total	100. 0	369	100. 0	101	27. 4	65	17. 6	36	9. 7	268	72. 6	74	20. 0	61	16. 5	91	24. 7	42	11. 5

TABLE 37.—*Disposition of 62 casualties with wounds of upper extremities and 81 casualties with wounds of lower extremities*

Disposition	Total living wounded		Fractures		Nonfractures	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Upper extremity wound					
Returned to duty from:						
Aid post	15	24. 2		0. 0	15	100. 0
First echelon	19	30. 6	3	15. 8	16	84. 2
Rear echelon	22	35. 5	7	31. 8	15	68. 2
Evacuated to United States	6	9. 7	5	83. 3	1	16. 7
Total	62	100. 0	15	24. 2	47	75. 8
	Lower extremity wound					
Returned to duty from:						
Aid post	17	21. 0		0. 0	17	100. 0
First echelon	15	18. 5		. 0	15	100. 0
Rear echelon	37	45. 7	9	24. 3	28	75. 7
Evacuated to United States	12	14. 8	7	58. 3	5	41. 7
Total	81	100. 0	16	19. 8	65	80. 2

[1] Percent for dichotomy, fractures versus nonfractures, under each disposition category and for total fractures versus nonfractures by upper and lower extremity wounds.

CAUSATIVE AGENTS

The number of battle casualties produced by various weapons depends upon many factors, such as the type of warfare (defensive, offensive, patrol); the number of weapons; the ammunition available; the training of personnel on both sides; tactics; terrain; and weather. This study presents the various types of casualties produced because the enemy used their weapons to advantage at a particular time. It does not show the maximum effectiveness of any weapon, information which could be obtained only from a controlled experiment. The study does show, however, certain facts about the weapons employed and about the way they were employed which can reasonably be expected to be approximated in future campaigns.

The effectiveness of a particular weapon can be determined by studying the percentage of deaths among the total number of casualties caused by it. This percentage, which is termed the weapon's "relative lethal effect," is shown in table 38.

TABLE 38.—*Distribution of 369 battle casualties, by relative lethal effect of causative agent*

Causatvie agent	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Machinegun	119	32. 3	53	44. 5	66	55. 5
Rifle	94	25. 5	24	25. 5	70	74. 5
Mortar	62	16. 8	10	16. 1	52	83. 9
Grenade	52	14. 1	6	11. 5	46	88. 5
Artillery	33	8. 9	6	18. 2	27	81. 8
Miscellaneous	9	2. 4	2	22. 2	7	77. 8
Total	369	100. 0	101	27. 4	268	72. 6

[1] Percent for dichotomy, dead versus living, by each causative agent and for total dead versus living.

In the Bougainville survey (ch. V), mortars caused the greatest number of casualties (38.7 percent) and had a relative lethal effect of 11.8 percent. The rifle ranked second, with 24.8 percent casualties and 32.2 percent relative lethal effect. In the New Georgia-Burma study, the machinegun leads with 32.3 percent casualties and a relative lethal effect of 44.5 percent. The higher effectiveness of this weapon would appear to be characteristic of jungle warfare.

Relation to Anatomic Distribution of Wounds

Table 39 presents a breakdown of the relative lethal effect of weapons as related to anatomic distribution of the wounds which they caused. The following comments seem warranted:

1. A comparison of wounds of the head and of the thorax indicates a considerable increase in the relative lethal effect in wounds of the thorax caused by both small arms and fragment-type wounds of the thorax. The figures might be interpreted as reflecting the protection provided by both the skull and the helmet.

2. Fragmentation-type weapons carried a very high relative lethal effect in abdominal wounds, obviously because of the ease with which the abdomen is penetrated and the subsequent high mortality rate. The machinegun also carried a very high lethal effect in abdominal wounds, but there were no deaths in this group as a result of rifle wounds.

3. The relative lethal effect for all weapons was very low for wounds of the extremities.

4. Of the 61 casualties with multiple wounds, 32 (52.5 percent) were wounded by fragmentation weapons. Among the 26 surviving casualties who were wounded by shell fragments, 59 percent returned to duty from the first echelon and 31.7 percent from the second echelon.

Since relatively few deaths result from wounds of the extremities, the effectiveness of weapons in relation to them must be judged by the disposition

of the casualty. Since fractures were one of the chief reasons for evacuation to the United States, the relative effectiveness of weapons on the extremities can also be judged by the number of fractures they cause. Table 40 contains these data. As might be expected, small arms were generally more effective than fragments in producing fractures.

TABLE 39.—*Relative lethal effect of weapons, by anatomic location of wounds and for multiple wounds*

Causative agent	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Head wounds					
Machinegun	25	33. 8	16	64. 0	9	36. 0
Rifle	20	27. 0	9	45. 0	11	55. 0
Mortar	11	14. 9	2	18. 2	9	81. 8
Grenade	10	13. 5	1	10. 0	9	90. 0
Artillery	6	8. 1	3	50. 0	3	50. 0
Miscellaneous	2	2. 7	1	50. 0	1	50. 0
Total	74	100. 0	32	43. 2	42	56. 8
	Thoracic wounds					
Machinegun	18	28. 6	13	72. 2	5	27. 8
Rifle	21	33. 3	13	61. 9	8	38. 1
Mortar	10	15. 9	3	30. 0	7	70. 0
Grenade	8	12. 7	2	25. 0	6	75. 0
Artillery	6	9. 5	1	16. 7	5	83. 3
Total	63	100. 0	32	50. 8	31	49. 2
	Abdominal wounds					
Machinegun	11	44. 0	8	72. 7	3	27. 3
Rifle	6	24. 0	--------	. 0	6	100. 0
Mortar	5	20. 0	1	20. 0	4	80. 0
Grenade	2	8. 0	1	50. 0	1	50. 0
Artillery	1	4. 0	1	100. 0	--------	. 0
Total	25	100. 0	11	44. 0	14	56. 0

See footnote at end of table.

TABLE 39.—*Relative lethal effect of weapons, by anatomic location of wounds and for multiple wounds*—Continued

Causative agent	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Upper extremity wounds					
Machinegun	18	28.6		0.0	18	100.0
Rifle	23	36.5		.0	23	100.0
Mortar	7	11.1		.0	7	100.0
Grenade	10	15.9	1	10.0	9	90.0
Artillery	5	7.9		.0	5	100.0
Total	63	100.0	1	1.6	62	98.4
	Lower extremity wounds					
Machinegun	24	28.9	2	8.3	22	91.7
Rifle	21	25.3		.0	21	100.0
Mortar	13	15.7		.0	13	100.0
Grenade	11	13.3		.0	11	100.0
Artillery	10	12.0		.0	10	100.0
Miscellaneous	4	4.8		.0	4	100.0
Total	83	100.0	2	2.4	81	97.6
	Multiple wounds					
Machinegun	23	37.7	14	60.9	9	39.1
Rifle	3	4.9	2	66.7	1	33.3
Mortar	16	26.2	4	25.0	12	75.0
Grenade	11	18.1	1	9.1	10	90.9
Artillery	5	8.2	1	20.0	4	80.0
Miscellaneous	3	4.9	1	33.3	2	66.7
Total	61	100.0	23	37.7	38	62.3

[1] Percent for dichotomy, dead versus living, by each causative agent and for total dead versus living by anatomic location of wounds and for multiple wounds.

As table 41 shows, small arms were responsible for 77 (76.3 percent) of the 101 casualties KIA and DOW. The proportion for the same group in the Bougainville campaign was 58.2 percent.

Neither the New Georgia-Burma nor the Bougainville records contain any information concerning the effect of U.S. weapons on enemy dead. It is

TABLE 40.—*Relative effect of weapons causing wounds of upper and lower extremities, among the living wounded*

Causative agent	Total wounds		Fractures		Nonfractures	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Upper extremity					
Machinegun	18	29.0	5	27.8	13	72.2
Rifle	23	37.1	7	30.4	16	69.6
Mortar	7	11.3	1	14.3	6	85.7
Grenade	9	14.5	2	22.2	7	77.8
Artillery	5	8.1		.0	5	100.0
Total	62	100.0	15	24.2	47	75.8
	Lower extremity					
Machinegun	22	27.2	8	36.4	14	63.6
Rifle	21	26.0	3	14.3	18	85.7
Mortar	13	16.0	2	15.4	11	84.6
Grenade	11	13.6		.0	11	100.0
Artillery	10	12.3	2	20.0	8	80.0
Miscellaneous	4	4.9	1	25.0	3	75.0
Total	81	100.0	16	19.8	65	80.2

[1] Percent for dichotomy, fracture versus nonfracture, by each causative agent and for total fracture versus nonfracture, by upper and lower extremity wounds.

TABLE 41.—*Distribution of 101 fatal casualties, by relative effect of causative agent*

Causative agent	Total dead		Killed in action		Died of wounds	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Machinegun	53	52.5	37	69.8	16	30.2
Rifle	24	23.8	16	66.7	8	33.3
Mortar	10	9.9	6	60.0	4	40.0
Grenade	6	5.9	3	50.0	3	50.0
Artillery	6	5.9	2	33.3	4	66.7
Miscellaneous	2	2.0	1	50.0	1	50.0
Total	101	100.0	65	64.4	36	35.6

[1] Percent for dichotomy, killed in action versus died of wounds, by causative agent and for total killed in action versus died of wounds.

characteristic of U.S. troops to use all firepower available, which means that there was a high incidence of wounds per enemy casualty. This consideration, together with other factors, made it impossible to gather reliable information on this phase of the survey.

Relative Lethal Effect of U.S. Weapons on U.S. Casualties

Table 42 lists 66 U.S. casualties caused by U.S. weapons fired by U.S. soldiers, chiefly because of mistaken identity; leaving foxholes at night; and accidental discharges and shorts from artillery and mortar fire.

Table 43 presents the disposition of these casualties.

Relative Lethal Effect of Weapons on Disposition of Casualties

A weapon can be evaluated by the disposition of the casualties it causes in addition to the number of wounds it produces in each body area. The criterion of disposition furnishes an excellent means of predicting what percentage of casualties injured by various weapons will be killed instantly or die later, what percentage of returns to duty will occur within certain time periods, and what proportion of casualties wounded in various body areas will survive.

Table 44 lists the disposition of casualties in relation to the various types of weapons which caused their wounds. Those who returned to duty usually returned within 30 days or less from first echelon hospitals and within 120 days or less from second echelon hospitals.

As this table shows, a very high proportion (60.5 percent) of all machinegun casualties were considered as "lost to the service." This group includes the total KIA (53) plus the number evacuated to the United States (19). A considerable number of those evacuated could, of course, continue in service after a period of hospitalization.

TABLE 42.—*Relative lethal effect of U.S. weapons on 66 U.S. casualties*

Weapons	Total casualties		Dead		Living wounded	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Machinegun	3	4. 5	1	33. 3	2	66. 7
Rifle	19	28. 8	8	42. 1	11	57. 9
Mortar	15	22. 7	4	26. 7	11	73. 3
Grenade	8	12. 1	2	25. 0	6	75. 0
Artillery	17	25. 8	1	5. 9	16	94. 1
Miscellaneous	4	6. 1	--------	. 0	4	100. 0
Total	66	100. 0	16	24. 2	50	75. 8

[1] Percent for dichotomy, dead versus living, by each weapon and for total dead versus living.

TABLE 43.—*Disposition of 66 U.S. casualties produced by U.S. weapons, by category*

Category	Casualties	
	Number	Percent
Dead:		
Killed in action	11	16.7
DOW (died of wounds)	5	7.6
Total	16	24.3
Wounded, living:		
Returned to duty from:		
Aid station	15	22.7
First echelon	8	12.1
Rear echelon	19	28.8
Evacuated to United States	8	12.1
Total	50	75.7
Grand total	66	100.0

The rifle was second to the machinegun in the production of casualties, but only 31.9 percent of the casualties it caused (24 KIA plus 6 evacuated to the United States) were lost to the service. Fragmentation-type weapons closely approximated the rifle in effectiveness.

The grenade continued to have the lowest relative lethal effect and the highest return to duty rate in the casualties it caused.

To demonstrate further the relative effectiveness of various weapons, tables 45 and 46 were prepared from the figures listed in table 44. These tables show:

1. Very few casualties with small arms wounds returned to duty from the first echelon (7.6 percent machinegun and 14.9 percent rifle).

2. The majority of small arms casualties were either KIA or were evacuated to the rear echelon or to the United States (84.0 percent machinegun and 67 percent rifle).

3. The rest of casualties wounded by small arms were returned to duty from the battalion aid station.

4. Approximately 21 percent of the casualties with wounds caused by mortars and 24 percent of those with wounds caused by artillery fire returned to duty from first echelon hospitals.

TABLE 44.—*Relative effect of weapons on disposition of casualties*

Causative agent	Total casualties		Total dead		Casualties returned to duty								Casualties evacuated to United States	
					Total		From aid station		From first echelon		From rear echelon			
	Number	Percent	Number	Percent [1]	Number	Percent [1]	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Machinegun	119	33. 1	53	44. 5	47	39. 5	10	21. 3	9	19. 1	28	59. 6	19	16. 0
Rifle	94	26. 1	24	25. 5	64	68. 1	17	26. 6	14	21. 9	33	51. 5	6	6. 4
Mortar	62	17. 2	10	16. 1	44	71. 0	21	47. 7	13	29. 6	10	22. 7	8	12. 9
Grenade	52	14. 4	6	11. 5	42	80. 8	16	38. 1	16	38. 1	10	23. 8	4	7. 7
Artillery	33	9. 2	6	18. 2	23	69. 7	8	34. 8	8	34. 8	7	30. 4	4	12. 1
Total	360	100. 0	99	27. 5	220	61. 1	72	32. 7	60	27. 3	88	40. 0	41	11. 4

[1] Percent for trichotomy, dead versus duty versus evacuated to United States, by each causative agent and for total dead versus duty versus evacuated to United States.

TABLE 45.—*Relative effect of weapons: Casualties returned to duty from first echelon*

Weapon	Total casualties	Casualties returned to duty	
		Number	Percent of total
	Number		
Machinegun	119	9	7. 6
Rifle	94	14	14. 9
Mortar	62	13	21. 0
Grenade	52	16	30. 8
Artillery	33	8	24. 2

TABLE 46.—*Relative effect of weapons: Casualties lost to combat duty (dead or evacuated to the rear echelon or to the United States)*[1]

Weapon	Total casualties	Casualties lost to combat	
		Number	Percent of total
	Number		
Machinegun	119	100	84. 0
Rifle	94	63	67. 0
Mortar	62	28	45. 2
Grenade	52	20	38. 5
Artillery	33	17	51. 5

[1] This includes men who were lost to immediate combat. It also includes men who could perhaps have offered resistance to the enemy for hours or days in spite of their wounds.

Casualties "Lost to Combat"

A final method of determining the effectiveness of weapons is presented in table 47, the basis of which is the casualties lost to combat because they were killed in action or because they were so incapacitated that they would be unable to fight under any circumstances.

The Bougainville report utilized a number of traumatic conditions by which to evaluate the seriousness of wounds. The same criteria were used in the analysis of the New Georgia-Burma casualties to determine those who were classified as "Lost to Combat":

1. Wounds of the head and central nervous system that produced unconsciousness and paralysis.
2. Wounds of intrathoracic structures that produced hemorrhage and shock.
3. Wounds of intraperitoneal structures that produced hemorrhage and shock.
4. Wounds of the extremities that produced fractures of the long bones, severance of major vessels, or major traumatic amputations.
5. Extensive soft-tissue wounds that produced shock.

TABLE 47.—*Relative effect of weapons: Casualties lost immediately to combat* [1]

Weapon	Total casualties	Casualties lost to combat	
		Number	Percent of total
	Number		
Machinegun	119	66	55. 5
Rifle	94	36	38. 3
Mortar	62	15	24. 2
Grenade	52	9	17. 3
Artillery	33	12	36. 4

[1] This includes men who could not have fought during any period before evacuation or death, their injuries putting them immediately out of action.

CIRCUMSTANCES OF WOUNDING

In addition to determining the relative effectiveness of various weapons, the survey unit was interested in evaluating the circumstances in which casualties were produced. Information collected concerning the position of the casualty when he was hit, the available protection, the type of action, and the distance from the wounding agent was classified under the following headings:

1. The cover group:
   a. Best protection (in a pillbox, usually constructed of heavy logs).
   b. Moderate protection (in a foxhole or trench with no overhead cover).
   c. Least protection (a tree, shallow hole, or log; or in the open with no protection at all).
2. The position of the casualty:
   a. Standing (includes walking and running).
   b. Sitting (includes crouching or kneeling).
   c. Prone.
3. The type of action:
   a. Patrol (small groups moving through jungle often determine the presence of the enemy by running into fire).
   b. Defensive (troops usually dug in with fixed positions).
   c. Offensive (applied to attack which develops after the enemy has been located by patrol activity).

Influence of Cover

Table 48 presents the influence of cover on the production of casualties by the various wounding agents.

In the Bougainville report, 20.1 percent of 1,557 casualties were wounded in well-covered pillboxes or well-dug holes (p. 418). This report shows that the pillbox offers relatively greater protection against aimed fire.

In the New Georgia-Burma survey, pillboxes were not used because of the offensive-type action and the extremely fluid frontlines. Only one man was hit in a pillbox, which was of Japanese construction. The bullet passed between the logs and killed him, which could not have occurred if the pillbox had been properly constructed.

Of the 369 casualties, 17.5 percent were wounded in foxholes, many of which were of poor construction. A well-constructed foxhole offers excellent protection from flat trajectory weapons but not as good protection from shell fragments, particularly when there are a number of tree bursts.

TABLE 48.—*Distribution of 349 casualties, by position and protection and by causative agent*

Position and protection	Causative agent					Total casualties	
	Rifle	Machine-gun	Grenade	Mortar	Artillery	Number	Percent
Standing:							
No cover	43	76	22	17	3	161	46.1
Partial cover	1	1	------	------	------	2	.6
Total	44	77	22	17	3	163	46.7
Sitting:							
No cover	20	3	1	15	1	40	11.5
Partial cover	4	1	------	------	------	5	1.4
Total	24	4	1	15	1	45	12.9
Prone:							
No cover	15	29	12	3	8	67	19.2
Partial cover	2	1	3	6	------	12	3.4
Total	17	30	15	9	8	79	22.6
Pillbox	------	1	------	------	------	1	.3
Trench hole	13	3	10	15	20	61	17.5
Total	13	4	10	15	20	62	17.8
Grand total	98	115	48	56	32	349	100.0

Influence of Position

The influence of position can be used to determine whether the number of hits depends solely upon the body surface exposed or is greater for aimed fire (table 49). For both aimed and unaimed fire, twice as many casualties occurred among standing as among prone soldiers. When the factor of cover

is removed (table 50), the relative proportions remain about the same, which is what might be expected if all missiles were unaimed and were traveling at random. In this jungle study, apparently a considerable proportion of all casualties resulted from random unaimed hits.

Rifles and machineguns are considered aimed weapons. Weapons which produce shell fragments, such as mortars, artillery, and grenades, are unaimed weapons. Bullets in jungle warfare came largely from weapons aimed only in the approximate direction and elevation.

The Japanese utilized their aimed weapons (rifle and machinegun) most efficiently when U.S. troops were on patrol or on offensive action (table 51). Their unaimed weapons (mortar, grenade, artillery) were used to best advantage when they were on the offensive or U.S. troops were on the defensive.

TABLE 49.—*Distribution of 287 casualties, by aimed and random fire and by position (with and without cover)*

Position	Aimed fire [1]		Random fire [2]		Casualties	
	Number	Percent	Number	Percent	Number	Percent
Standing	121	61. 7	42	46. 1	163	56. 8
Sitting	28	14. 3	17	18. 7	45	15. 7
Prone	47	24. 0	32	35. 2	79	27. 5
Total	196	100. 0	91	100. 0	287	100. 0

[1] Rifle and machinegun.
[2] Mortar, artillery, and grenade.

TABLE 50.—*Distribution of 270 casualties, by aimed and random fire and by position (no cover)*

Position	Aimed fire [1]		Random fire [2]		Casualties	
	Number	Percent	Number	Percent	Number	Percent
Standing	119	64. 0	44	52. 4	163	60. 4
Sitting	23	12. 4	17	20. 2	40	14. 8
Prone	44	23. 6	23	27. 4	67	24. 8
Total	186	100. 0	84	100. 0	270	100. 0

[1] Rifle and machinegun.
[2] Mortar, artillery, and grenade.

TABLE 51.—*Distribution of 362 casualties, by type of action and causative agent*

Causative agent	Total casualties		Patrol		Defensive		Offensive	
	Number	Percent	Number	Percent [1]	Number	Percent [1]	Number	Percent [1]
Aimed weapon:								
Rifle	96	43.8	15	15.6	46	47.9	35	36.5
Machinegun	123	56.2	47	38.2	23	18.7	53	43.1
Total	219	100.0	62	28.3 (86.1)	69	31.5 (45.1)	88	40.2 (64.2)
Unaimed weapon:								
Mortar	62	43.4	1	1.6	40	64.5	21	33.9
Grenade	50	35.0	9	18.0	13	26.0	28	56.0
Artillery	31	21.6	------	.0	31	100.0	------	.0
Total	143	100.0	10	7.0 (13.9)	84	58.7 (54.9)	49	34.3 (35.8)
Grand total	362	100.0	72	19.9	153	42.3	137	37.8

[1] Percent for trichotomy, patrol versus defensive versus offensive, by type weapon, and for total patrol versus defensive versus offensive.

NOTE.—Figures in parentheses express percent of total type of weapon for total type of activity.

Influence of Range of Small Arms Missiles

Any information that can be collected concerning the range of small arms or the distance from a shellburst at the time of wounding is of extreme importance in assessing the wounding potential of a weapon, as well as in designing and constructing personnel armor. If the weight of the bullet or fragment is known, plus its approximate velocity (by interpolation from range or distance values), the kinetic energy of the missile at the time of impact can be determined. All of these data are of interest and of fundamental importance in the basic studies on wound ballistics. (See chapters II and III.)

Table 52 presents the data on 208 casualties (93 from rifle fire and 115 from machinegun fire) in which the approximate range was known. As the table shows, the greater number of injuries occurred at distances under 75 yards. The observation is typical of jungle warfare, in which small arms are seldom actually aimed at distances greater than 50 yards.

Table 53 presents the data on 85 casualties (56 from mortar and 29 from artillery fire) in which the range was known. The majority of the injuries occurred at distances under 10 yards from the burst. The enemy hand grenade was seldom effective as a wounding agent at distances greater than 3 yards (table 54).

TABLE 52.—*Distribution of 208 casualties, by category and by approximate range of small arms (rifle and machinegun) missiles*

Approximate range (yards) of small arms missile	Dead	Living wounded		Total casualties
		Returned to duty	Evacuated to United States	
Rifle:	*Number*	*Number*	*Number*	*Number*
0 to 25	8	13	2	23
25 to 50	5	4	1	10
50 to 75	2	26	2	30
Over 75	7	22	1	30
Total	22	65	6	93
Machinegun:				
0 to 25	7	2	3	12
25 to 50	8	5	3	16
50 to 75	23	18	6	47
Over 75	15	22	3	40
Total	53	47	15	115
Grand total	75	112	21	208

TABLE 53.—*Distribution of 85 casualties wounded by mortar and artillery shells, by distance from point of burst of causative agent*

Distance (yards) from point of burst of causative agent	Dead	Living wounded		Total casualties
		Returned to duty	Evacuated to United States	
Mortar shells:	*Number*	*Number*	*Number*	*Number*
0 to 10	8	35	6	49
10 to 20	1	5	1	7
20 to 50				
Over 50				
Total	9	40	7	56
Artillery shells:				
0 to 10	6	7		13
10 to 20		4		4
20 to 50		1	3	4
Over 50		8		8
Total	6	20	3	29
Grand total	15	60	10	85

TABLE 54.—*Distribution of 47 casualties wounded by hand grenade, by distance from detonation of causative agent*

Distance from detonation of causative agent (yards)	Dead	Number of casualties		Total
		Returned to duty	Evacuated to United States	
0 to 3	6	28	4	38
3 to 5		9		9
Over 5				
Total	6	37	4	47

In summary, the following distances were typical for the offensive type action which characterized the New Georgia-Burma fighting:

Records show that 90 percent of the dead killed by bullets were hit at ranges under 100 yards. Furthermore, many of these bullets had low velocities because they had passed through brush or trees. Mortars and artillery seldom killed at distances greater than 10 yards from the burst, and close to 100 percent of casualties from these weapons occurred at less than 50 yards. No records are available that show men killed at distances greater than 5 yards from a grenade burst.

Over 75 percent of casualties killed by fragments from mortar and artillery shells were less than 10 yards from the source of the fragments.

Over 80 percent of casualties killed by fragments from hand grenades were less than 3 yards from the detonation.

DISPOSITION OF CASUALTIES

A review of the disposition of battle casualties furnishes much valuable information. In the type of warfare discussed in this chapter, between 16 and 25 percent of all men hit were killed. Approximately the same proportions were returned to duty immediately, and 40 percent were returned to duty within 4 months. The remaining 10 to 15 percent were evacuated to the United States.

Disposition According to Anatomic Distribution of Wounds

The anatomic distribution of wounds played the most important role in the disposition of casualties:

1. Casualties who received wounds of the head, chest, or abdomen had a 50-percent chance of being killed in action. Of those who survived penetrating wounds of the head, chest, or abdominal cavity, only a very few could be returned to duty. Most of the men with wounds in these three areas who

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could be returned to duty had only flesh wounds. In these areas, a little protection might have made the difference between death or disability and a minor wound.

2. More than three-quarters of all casualties with wounds of the extremities returned to duty without leaving the theater of action. Fatalities due to these wounds were so few as to be insignificant. When they occurred, most of then could be attributed to carelessness.

Disposition According to Causative Agent

Disposition of casualties according to the agents which caused their wounds was one way of establishing the effectiveness of weapons used by Japanese infantry. In descending order of effectiveness, these weapons were machinegun, rifle, artillery, mortar, and grenade.

Machineguns of a caliber equivalent to that of rifles caused greater losses than rifles principally because they caused multiple wounds involving multiple regions. Sixty percent of all casualties struck by machinegun bullets were lost to service, a proportion which conclusively demonstrates the deadly effectiveness of this and other automatic weapons.

Shell fragments did not approach the effectiveness of bullets unless they hit men who were upright and unprotected or the shell had a tree burst.

Artillery and mortars, as employed in the Pacific areas with little use of time fuzes, were much more effective than grenades, which, as already noted, seldom killed at distances greater than a few feet. Artillery and mortars accounted for about 30 percent of men lost to service (casualties killed or evacuated to the United States) in each of their respective categories.

When casualties killed in action, those evacuated to the rear echelons, and those evacuated to the United States are totaled, a comparison of the wounds produced by each weapon provides figures which further substantiate the results just cited. The machinegun leads with 84 percent and the grenade comes last with 38.5 percent. The ratio remains the same when the dead are added to the group of men who could not continue to fight for even a short time in an emergency. On the other hand, casualties who returned to duty from the first echelon did so with increasing frequency according to whether they were wounded by grenades, mortars, artillery, rifles, or machineguns.

About 75 percent of the 101 dead in the New Georgia-Burma survey died because of wounds from small arms. Two-thirds of these fatalities were caused by machineguns, generally the .25 caliber weapon that the Japanese used as the equivalent of the U.S. Browning automatic rifle. A large but undetermined number of Japanese casualties were caused by U.S. automatic weapons: In a single brief engagement involving only one combat team, two U.S. heavy machineguns fired 10,000 rounds, and more than 400 Japanese were killed.

In the type of warfare in which troops tended to seek cover in natural vegetation and did not always build strong fortifications, the Browning auto-

matic rifle proved a very valuable weapon. The Japanese light machinegun also proved extremely effective against U.S. troops. With both of these weapons, it was possible to throw a large volume of fire rapidly into a group of men before any of them could assume prone positions. In jungle warfare, in which brief glimpses of the enemy were the rule, these automatic guns were decisive; a burst often caught men on their feet, with vital areas of their bodies exposed.

In this type of jungle warfare, tremendous U.S. artillery concentrations in all probability caused the largest percentage of Japanese casualties. On the other hand, the value of the automatic weapon, often firing initial bursts in the general direction of groups of enemy above ground, should not be underestimated.

The great value of time fuzes for artillery was well demonstrated by the large numbers of casualties U.S. troops sustained from the very light and inaccurate Japanese artillery fire when they were subjected to it while near trees and large bushes. The time fuze, when properly used, would certainly have been as effective as these so-called tree bursts.

INFLUENCE OF PROTECTIVE ARMOR

In the Bougainville study, head wounds exceeded the proportion predicted for the mean projected body area by twice the expected percentage. Wounds of the abdomen and lower extremities did not quite reach the theoretical number of hits for the mean projected body areas of these regions.

In the New Georgia-Burma report, as already noted, the expected proportion of wounds of the head is exceeded by 7.9 percent and of wounds of the thorax by 4.5 percent. Wounds of the lower extremities and abdomen, as in the Bougainville report, are below the expected proportions.

A great increase over the theoretical proportion of head injuries can be expected in defensive warfare. In fact, no matter what the type of warfare, wounds of the head can be expected to exceed the theoretical. Apparently this is also true of thoracic wounds. Adequate studies are not available for wounds of the back, front, and right and left sides of the body, but personal experience leads to the tentative conclusion that at least two-thirds of all hits in both dead and living will occur on the anterior body surface.

Table 55 presents the distribution and entrance sites of the lethal wounds in 173 casualties (78 in the New Georgia-Burma campaigns, 95 in the Bougainville campaign) who were killed in action with wounds of the head, chest, and abdomen. There is a decided concentration of wounds in the frontal region of the head and on the left side of the chest as compared to the right side.

The data secured when the total dead of all jungle campaigns were combined are shown in table 56.

Approximately 40 percent of U.S. dead had head wounds as the cause of death. The larger proportion of these casualties, however, showed no penetra-

tion of the helmet, thus indicating that ballistic protection was of some value. On the other hand, the coverage provided by the standard M1 helmet seemed inadequate to protect against the sort of missiles which entered the brain. Further investigation will be necessary to prove this point, but this study indicates that the greater percentage of head wounds, as well as the many deaths due to such wounds, could be prevented by a more scientifically designed helmet. Such a helmet should (1) be made of better armor material and (2) should also protect the brain from every approach, including a large part of the face. The unprotected upper portion of the face was the point of entrance for most missiles which penetrated the brain and produced lethal wounds. Casualties with superficial but severe injuries of the face and neck had an excellent chance for survival.

TABLE 55.—*Anatomic distribution of fatal wounds of the head, thorax, and abdomen in 173 casualties (95 Bougainville campaign; 78 New Georgia-Burma campaigns)*

Anatomic location	Region wounded		Total number of casualties
	Anterior	Posterior	
Head	49	11	60
Thorax	53	26	79
Abdomen	24	10	34
Total	126	47	173

TABLE 56.—*Distribution of lethal wounds in 496 casualties (395 Bougainville campaign; 101 New Georgia-Burma campaigns), by anatomic location (regional frequency)*

Anatomic location	Total casualties	
	Number	Percent
Head	176	35. 5
Thorax	119	24. 0
Abdomen	59	11. 9
Extremities	18	3. 6
Multiple	124	25. 0
Total	496	100. 0

As already mentioned, only an insignificant and largely unnecessary proportion of deaths were due to wounds of the extremities.

Practical experience with war dead, as well as knowledge of anatomy and of the possibilities of good surgery, leads to the conclusion that a great saving in life could be effected by the proper use of one square foot of armor on the anterior surface of the chest. The base figure of 60 (3¾ lb.) ounces per

square foot for armor capable of resisting 20 mm. fragments at close range provides a strong argument for such protection. The weight of this piece of equipment would not equal the 7-pound weight of the old-type gas mask. The equipment would certainly not be as cumbersome.

The possibility of designing the infantry rifle belt to increase its ability to resist low-velocity missiles should also be considered.[5]

U.S. CASUALTIES CAUSED BY U.S. MISSILES

Of the 369 casualties in New Georgia and Burma, 66 (17.9 percent) were caused by U.S. fire, as were 219 (12.2 percent) of the 1,788 Bougainville casualties. All types of weapons were represented, with rifle and artillery leading in both reports. It is doubtful that higher command is aware that U.S. soldiers killed and wounded such a large proportion of their fellow soldiers as these figures suggest. Accurate figures exist only for isolated reports, such as the reports for the Bougainville and the New Georgia-Burma campaigns.

There were a variety of reasons for this tragic situation: Individual carelessness, usually on the part of the men hit; poor training in the use of weapons: poor unit discipline; lack of dissemination of information; poor leadership; and faulty judgment.

Limited experience suggests that artillery casualties were for the most part due to poor fire direction by inexperienced observers and also suggests that many casualties could probably have been prevented if adequate containers had been provided for grenades and if the length of safety time had been stamped on each grenade.

The majority of rifle and machinegun casualties occurred at night and were caused by mistaken identity. In most instances the casualty showed poor judgment—he stood up in his foxhole; moved about the perimeter; entered a perimeter without proper caution; or performed other foolish acts.

Nearly all rifle and machinegun casualties in the group hit by U.S. fire occurred when U.S. units were in defensive positions, in which there was little need for hasty decisions. The men should have had more confidence in camouflage and in their ability with specific weapons. Good communications and a general knowledge of the tactical situation would also have appreciably reduced the number of such casualties.

Most self-inflicted wounds were caused by carelessness and were not intentional.

Methods of Prevention

A consideration of the circumstances in which each injury caused by U.S. fire occurred would include: (1) The position of the casualty; (2) the type of action; (3) the natural protection; (4) the terrain, time, and weather; (5) the

[5] These suggestions were made by Dr. Hopkins in 1944, immediately after he had completed his surveys. His remarks demonstrate the widespread interest in body armor on the part of many of the medical officers engaged in the initial treatment of battle casualties.—J. C. B.

type of weapon; (6) the range of the bullet or shellburst; (7) the planning of the operation; and (8) leadership. Some of these factors require discussion.

Position.—Too many commanding officers and their men apparently did not realize the protective value of the crawling position. Frequently, soldiers would hit the ground when firing commenced but rise to a semierect position in order to advance toward a known enemy position at short range. If a squad could knock out a pillbox in an hour of crawling, without casualties, there was no point to trying to do it in 30 minutes by advancing in a crouch and sustaining casualties. The odds were too great to justify the time saved.

The great value of the prone position should also be emphasized. Records available indicate that in jungle warfare very few men were hit when they stuck close to the ground. Of 646 casualties (460 in Bougainville and 186 in New Georgia and Burma) hit by bullets and without protection of any sort, only 146 were injured while prone. Of 788 casualties (704 in Bougainville and 84 in New Georgia and Burma) hit by shell fragments, only 233 were injured while prone.

Protection.—The value of protection is clear in figures from both the Bougainville and the New Georgia-Burma campaigns. In the Bougainville campaign, which was chiefly defensive, only 484 of the 1,906 men hit had protection of any sort. On New Georgia, 30 Japanese were killed at night inside the perimeter of the 1st Battalion, 148th Infantry. The U.S. troops were in shallow holes and did not have a single casualty. In the Burma campaign, a combat team of 450 men were well dug in on a river bend but had only open foxholes. During an enemy attack lasting 1 hour and 15 minutes, 400 Japanese were killed while trying to cross the river. Not a single U.S. soldier was killed, in spite of a tremendous concentration of Japanese machinegun and rifle fire. Three minor injuries were caused by mortar fragments. This illustration is only one of many possible examples of the value of even shallow foxholes.

Type of combat.—In the type of warfare encompassed by this survey, about 50 percent of the casualties occurred in defensive action. The Japanese, in spite of the great odds, usually attacked in the early morning or late afternoon. Well-indoctrinated troops, who were aware of this fact, could be prepared for the attacks by digging adequate foxholes, preparing fire lanes, and generally showing alertness.

A fair average for U.S. casualties caused by offensive action against the Japanese seems to be about 35 percent, while patrol activity accounts for 15 percent. In the patrol group, 75 percent of the casualties were probably caused by aimed weapons. In defensive and offensive warfare, aimed weapons accounted, respectively, for 30 and 60 percent of casualties.

The Japanese made use of defensive warfare and excelled in the use of terrain and camouflage for defensive purposes. In New Georgia, 16 of the 1st Battalion's initial casualties (5 dead and 11 wounded) were caused by fire from 2 enemy heavy machineguns covering a small bridge. These guns were placed in an area of thick jungle and steep hills which made flanking movements almost

impossible. The entire battalion was held up for 36 hours and did not locate the positions of the guns until the area had been pulverized by artillery and mortar fire.

In Burma, the enemy invariably set up trail blocks at the crests of steep hills, locations which usually provided perfect fire lanes and in which flanking was difficult. Nor did they neglect to have similar positions prepared in advance of a withdrawal.

Without pack artillery, dive bombers, expert use of mortars, and strafing (all in small quantities), it is doubtful that the 3d Battalion of Merrill's Marauders would ever have relieved the 2d Battalion after an offensive against one battalion of Japanese over a 5-mile jungle trail. The Japanese had favorable terrain, but the tree burst of U.S. artillery and mortars, plus close fighting with grenades, finally defeated them. The great effect of mortar and artillery tree bursts can hardly be overemphasized.

Leadership.—In accounting for U.S. combat casualties, the role of leadership is clearly evident. A careful review of the causes of casualties in New Georgia among men of the 1st Battalion, 148th Infantry, shows that a very large number of them could be explained by poor leadership, chiefly at the battalion and regimental level.

The Intelligence and Reconnaissance Platoon of the 3d Battalion of Merrill's Marauders in Burma accounted for approximately 400 Japanese casualties in 26 engagements with the loss of only 3 U.S. soldiers KIA. The platoon leader (1st Lt. Logan E. Weston, Inf.), who devised the tactical formation used by the platoon, was the man chiefly responsible for the small number of casualties. Incidentally, the health of this platoon was always relatively good, and it had an insignificant number of accidents during the campaign. The platoon realized the value of their particular standard operational procedures for patrol and for defensive and offensive activities. Their excellent record is largely attributable to the excellent leadership exercised by their platoon commander.

Other factors.—Poor distribution of plans and combat information was often responsible for injuries. Infantrymen participating in patrols and in offensive action in such circumstances did not understand the general purpose of the engagement.

Face and hand camouflage was seldom used by troops fighting jungle warfare, yet the split second of hesitation occasioned by camouflage might frequently be prolonged, with disastrous results for the enemy. This would be especially true on patrol activity but would also play an important part in any type of action in which aimed weapons might cause casualties.

Greater stress should have been laid on the necessity for foxholes, and their preparation and occupation should have been more strictly enforced by the unit command. More attention should have been given to the physical and mental condition, as well as to the personal needs, of the troops. Elective actions should not have been undertaken without adequate food and rest.

Needless casualties caused by neglect of the simple principles of self-preservation, firepower, sound tactics, and the physical well-being of the troops should not have been tolerated.

CONCLUSIONS

In the past, the attention of both Medical Corps and combat officers has been focused on the care of the wounded after they were injured. The purpose of this survey was to call attention to means of reducing the number of wounded and particularly the number of casualties killed in action. In other words, the point has now been reached when more consideration should be given to the individual U.S. soldier who, even with superior equipment and supplies, will be killed or wounded in combat.

Body armor has been used in warfare in the past and its weight willingly tolerated by soldiers once its effectiveness was demonstrated. The stakes for the individual and for the Army are so high that the most careful investigation of existing armor and experimentation with improved types of armor and helmets are fully justified.

In addition, all tactical lessons of combat should be exploited fully. The Army cannot afford to neglect any suggestion which promises to save the lives of U.S. citizens who are temporarily subject to its orders. It is believed that the survey reported in this chapter points to the possibility of saving many lives and avoiding many wounds.

CHAPTER V

Study on Wound Ballistics—Bougainville Campaign

Ashley W. Oughterson, M.D., Harry C. Hull, M.D., Francis A. Sutherland, M.D., and Daniel J. Greiner, M.D.

The purpose of the wound ballistics study [1] conducted on Bougainville was to obtain information on the relative effectiveness of different weapons as casualty-producing agents. To obtain this information, a study was made of all battle casualties (living and dead) which had occurred in the U.S. Army Ground Forces on Bougainville Island from 15 February to 21 April 1944.

Though it was possible to obtain information on all casualties, living or dead, for the entire period from 15 February to 21 April, post mortem examinations were limited to the interval from 22 March to 21 April. The number of autopsies was further curtailed because the bodies of some of those killed in action were not obtained before decomposition was far advanced. It was also hoped to study the effect of U.S. Army weapons on the enemy dead. The character of the fighting resulting in multiple wounds by rifle, machine-gun, grenade, mortar, and artillery fire made it almost impossible, however, to determine what weapon was responsible for death. Furthermore, because of delay in obtaining the Japanese dead, the state of deterioration frequently precluded post mortem examination. Also, during this period, it often required all the available personnel to perform post mortem examinations on U.S. Army killed-in-action casualties.

Since the effect of weapons may be observed on the living as well as the dead, a clinical appraisal especially with regard to end results was needed. Furthermore, the relative effect of weapons may be greatly influenced by the quality of medical care. For this reason, the ballistics team after completing the study in the forward area followed the patients through the hospitals of the rear echelon.

The battle casualties studied may be divided into two large groups: The killed in action and the wounded in action.

[1] In accordance with instructions from The Surgeon General, 21 January 1944, a team was organized for the purpose of conducting a study on wound ballistics. This team included Col. Ashley W. Oughterson, MC, Surgeon; Lt. Col. Harry C. Hull, MC, Surgeon; Maj. Francis A. Sutherland, MC, Surgeon; Maj. Daniel J. Greiner, MC, Pathologist; Sgt. Reed N. Fitch, T4g. Charles J. Berzenyi, and T5g. Charles R. Restife. The team was organized to participate in the contemplated New Ireland operation and was ordered to Guadalcanal for training and organization. The New Ireland operation was cancelled, and the team was then ordered on detached service with the XIV Corps on Bougainville and reported there on 22 March 1944.

Killed in action.—Those killed in action prior to 23 March were recorded in the graves registration files. While some of these records were excellent, many were inadequate. Information on the circumstances attending death, such as type of missile, distance from burst, terrain, time, and type of protection, was supplemented by personal interviews with the medical officers and aidmen or with comrades who, during the action, had seen the soldier killed or had seen him before he expired. This information is better obtained by personal interview than by questionnaire because the circumstances attending death are so varied. In order to obtain reasonably accurate data, evaluation of the situation by trained and interested personnel is necessary at the time of interview. Subsequent to 23 March 1944, all the dead were brought to the 21st Evacuation Hospital which was located near the cemetery. Here, excellent facilities and assistance for post mortem examinations were available. This work was carried on by the pathologist who was assisted by a clerk and a photographer. When the number of autopsies exceeded 10 or 12 per day, additional assistance was provided by the surgeons. A few additional post mortem examinations were obtained on those wounded in action who died later in hospitals of the rear echelon. A card index was kept on all wounded, and this was checked for death against the records of the hospitals in the rear echelon.[2] This check was made at a later date, and for the majority of patients, a period of 1 to 4 months had elapsed since they were wounded; hence, there is reason to believe that all or nearly all of the dead are recorded in this study.

Wounded in action.—The wounded in action fell into three groups: (1) The more seriously wounded who were evacuated from Bougainville, (2) the relatively minor wounds treated in the clearing stations or hospitals and returned to duty in 1 to 3 weeks, and (3) the very minor wounds and abrasions returned to immediate duty from the battalion aid and collecting stations. This latter group was not studied. The second group, of minor wounds treated and returned to duty from the clearing stations and hospitals, were studied in detail, as were those evacuated from the island. Factors relating to ballistics in the wounded in action were obtained by questionnaire and by personal interview. The personal interview was undoubtedly superior, but since these troops were still in battle it was sometimes impossible to obtain an interview with an eyewitness. When emergency medical tags and hospital records were checked with eyewitness accounts, many discrepancies were found as to the weapon, the distance, what the soldier was doing, and the exact circumstances surrounding his injury. Allied officers and enlisted men were questioned regarding effectiveness of enemy weapons and tactics, as well as their own. Questions were also asked regarding the construction of pillboxes and the use of camouflage with reference to their effectiveness as a means of protection.

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[2] Throughout this chapter, hospitals in the rear echelon refer to those on Guadalcanal, Espíritu Santo, and New Caledonia.—J. C. B.

FACTORS PECULIAR TO THE BOUGAINVILLE CAMPAIGN

Geography

Bougainville Island is in the northernmost part of the Solomon Islands group, lying between latitudes 50°28′ S. and 5°51′ S. It is approximately 130 miles long with an average width of 30 miles. It is a tropical island of volcanic origin with a backbone of rugged mountain ranges. Behind the Empress Augusta Bay sector, the Crown Prince Range rises to a height of 6,560 feet with an active volcano, Mount Bagana. The Empress Augusta Bay and Torokina Point sectors present a low sandy shoreline with heavy surf. The south shore of this island has very little coral, and behind the shoreline a sandy alluvial plain rises gently to the foothills of the Crown Prince Range, about 4,000 yards inland. Near the shore are some lagoons and in the region of the Torokina River extensive swamps. The subsoil of the plain is black volcanic sand providing good drainage. The rainfall which is fairly uniform throughout the year averages approximately 11 inches per month. The typical heavy tropical showers wash and erode the hillsides and make constant road maintenance a necessity.

The Empress Augusta Bay beachhead was virgin jungle except for a small coconut plantation on Torokina Point. The elaborate system of roads shown in the situation map (fig. 159) had all been built since the initial landing during the first week of November 1943. At the time of the enemy attack on 8 March 1944, this system of roads was nearly completed except for a section of the perimeter road connecting the Americal and 37th Division sectors. The perimeter at its greatest depth was carried along the high ridges of the foothills, and this extremely rugged terrain presented a major problem in evacuation where roads were not present or were under fire. This road system alone played an important role in saving the lives of many casualties which might otherwise have been lost. However, the problem of evacuation of wounded within the perimeter was simple when compared to the difficulties encountered in evacuating men wounded on patrol. Patrols constantly covered this rugged terrain beyond the perimeter for distances of 1,000 to 8,000 yards. Even a 1,000-yard carry over these ridges and draws was exhausting to both the litter bearers and the patient.

Medical Installations and Routes of Evacuation

The medical installations and routes of evacuation (fig. 153) were better developed on Bougainville at the time of the attack than for any other island campaign in the South Pacific. This was due to the fact that the beachhead had been developed steadily over a period of 4 months before the Battle of the Perimeter began.

U.S. Army photo

FIGURE 153.—One of the routes of evacuation between the clearing station of the Americal Division and the 21st Evacuation Hospital.

Two-way all-weather roads made all parts of the perimeter easily accessible with one exception. This one sector lay near the boundary line between the Americal and 37th Divisions, where the perimeter road had not been completed (fig. 154). Furthermore, the roads were kept open throughout the battle except on Hill 700. The one-way all-weather road over very rugged terrain leading to the latter Hill was for a time under enemy fire, and as a result a difficult litter carry of 1,200 yards was necessary during the attack. Later at this point, and at others where sporadic fire was encountered, half-tracks were used for evacuation, and patients were then transferred to jeep ambulances and taken to the hospital. The greatest distance from the frontline to a clearing station was found on the Americal sector at the mouth of the Torokina River which was approximately 10, 000 yards over a good road. Figure 155 is an illustration of the type of road which existed outside of the perimeter area.

Owing to this excellent system of good roads, the majority of patients arrived at the hospitals within 3 hours, and frequently within an hour. A sample of 142 patients showed that 87 percent were on the operating table within 3 hours. Patrol missions presented the most difficult problems of evacuation. Small patrols, frequently no larger than a platoon, were so numerous that it was impractical to send a medical officer with each one. Larger combat patrols were usually accompanied by a medical officer. On only one occasion, however, was a patrol large enough to warrant the use of a portable surgical hospital. As a consequence, some patients who were wounded on patrol did not reach the hospital until after 24 to 48 hours had elapsed. However, every effort was

U.S. Army photo

FIGURE 154.—Perimeter road near junction of Americal and 37th Divisions. A good route of evacuation over difficult terrain built by the 117th Engineer Combat Battalion.

U.S. Army photo

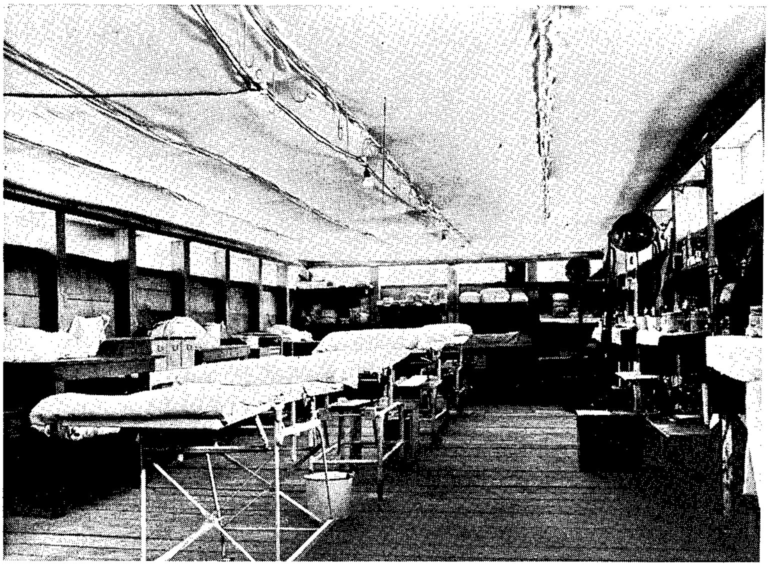
FIGURE 155.—Roadway along the Laruma River, outside the perimeter.

made to reduce delay to the minimum and to provide surgery at the earliest possible moment.

The medical installations available for the Bougainville campaign were more than adequate. The clearing stations of both the Americal and 37th Divisions had been augmented with additional surgical equipment before the hospitals were established on the beachhead. The 31st Portable Surgical Hospital had been assigned to the Americal Division and the 33d Portable Surgical Hospital, to the 37th Division. Owing to the fact that more adequate medical facilities became available later, the portable surgical hospitals were not necessary, although they were both utilized. The 52d Field Hospital was utilized for the care of service troops and functioned chiefly as a station hospital for the island. The 21st Evacuation Hospital (figs. 156 and 157), an affiliated unit from the University of Oklahoma, Norman, Okla., had an exceptionally well qualified staff, including the various specialists. The construction of this hospital was completed on 8 March 1944; however, the hospital had functioned for a limited number of patients since 15 February. The normal capacity of the 21st Evacuation Hospital was 750 beds with facilities available for an additional 250 beds (fig. 158). Casualties from all combat troops were cared for at this hospital. Since the 21st Evacuation Hospital was situated only 4,000 yards from the frontlines at the nearest point of attack (forward of some artillery batteries), the majority of the seriously wounded patients were sent directly to the hospital to avoid delay at the clearing stations.

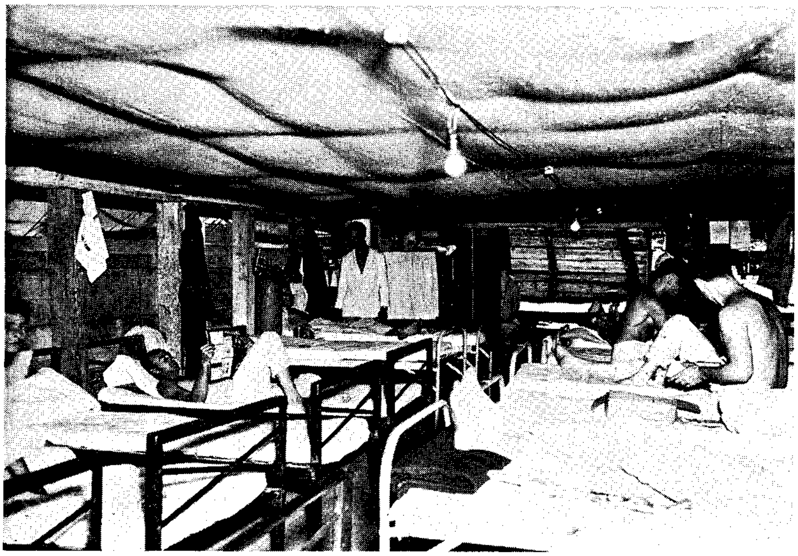
U.S. Army photo

FIGURE 156.—Ward area of the 21st Evacuation Hospital on Bougainville.



U.S. Army photo

FIGURE 157.—Underground operating room of the 21st Evacuation Hospital on Bougainville. There was a similar operating room aboveground providing space for eight tables.



U.S. Army photo

FIGURE 158.—Interior of underground ward, 21st Evacuation Hospital on Bougainville. Space was provided for 120 litter patients. This would have been inadequate if shelling had been heavy.

All patients from the island were evacuated through the 21st Evacuation Hospital. Nearly all patients evacuated to the rear were sent by air transport to Guadalcanal and were cared for there in one of three 500-bed station hospitals. Patients requiring a long period of convalescence were evacuated from Bougainville by ship or air transport to Espíritu Santo and to New Caledonia.

Allied and Japanese Forces

Allied forces on Bougainville were concentrated in the Empress Augusta Bay beachhead. The perimeter line of defense had been extended previously in three phases until, by the time of the Japanese attack on 8 March 1944, it enclosed about 20 square miles and was approximately 22,000 yards in length. The total strength within this perimeter as of 31 March 1944 was 60,583. Included were 11,220 Navy and Marine personnel and civilians. The few casualties from these groups were due mostly to shelling and bombing and are not included in this study. The casualties included in this study were derived, therefore, from a total strength of 49,363. Of this number, 40,404 were U.S. Army Ground Force combat troops of which 27,831 constituted the 37th and Americal Divisions. The remainder of the ground force combat troops were attached to the XIV Corps and the 25th Regimental Combat Team. Allied forces other than U.S. troops, chiefly Royal New Zealand Air Force and Fijian Infantry, numbered 3,424. It should be noted that, of these forces, the number actually involved in combat was comparatively few. This number could not be ascertained except for certain specific engagements. The perimeter line of defense was divided between the 37th and Americal Divisions although other forces were used in the line at various times. The Fijian troops, among whom there were a considerable number of casualties, were used chiefly on patrol missions.

Immediately before the attack, the effective strength of the Japanese Army and Navy forces on Bougainville numbered about 27,000. Of these, about 18,000 were believed to be Army combat troops. The remaining strength consisted of Army and Navy antiaircraft, base, service, and labor troops. No surface ships had been observed in the Bougainville area since mid-November 1943 and whatever supplies were brought in were carried by submarine or barge. With the exception of small arms ammunition, there was evidence that the enemy was short of basic supplies. Although elements of the *17th Division* (one battalion each from the *81st* and *53d Infantry Regiments*) were identified in the Torokina area, the brunt of the attack was borne by the Japanese *6th Division*. The backbone of the enemy's strength was the *13th, 23d,* and *45th Infantry Regiments* (fig. 159). These units were supported by the *6th Field Artillery Regiment* (*2d Battalion*) elements of the *4th Heavy* (*Medium*) *Artillery Regiment,* as well as miscellaneous mortar, artillery, engineer, and road construction units. The *1st Battalion, 13th Infantry* (minus one company), was to be the division reserve. The total strength of these units actually in combat in the Battle of the Perimeter was believed to be only slightly more than 10,000.

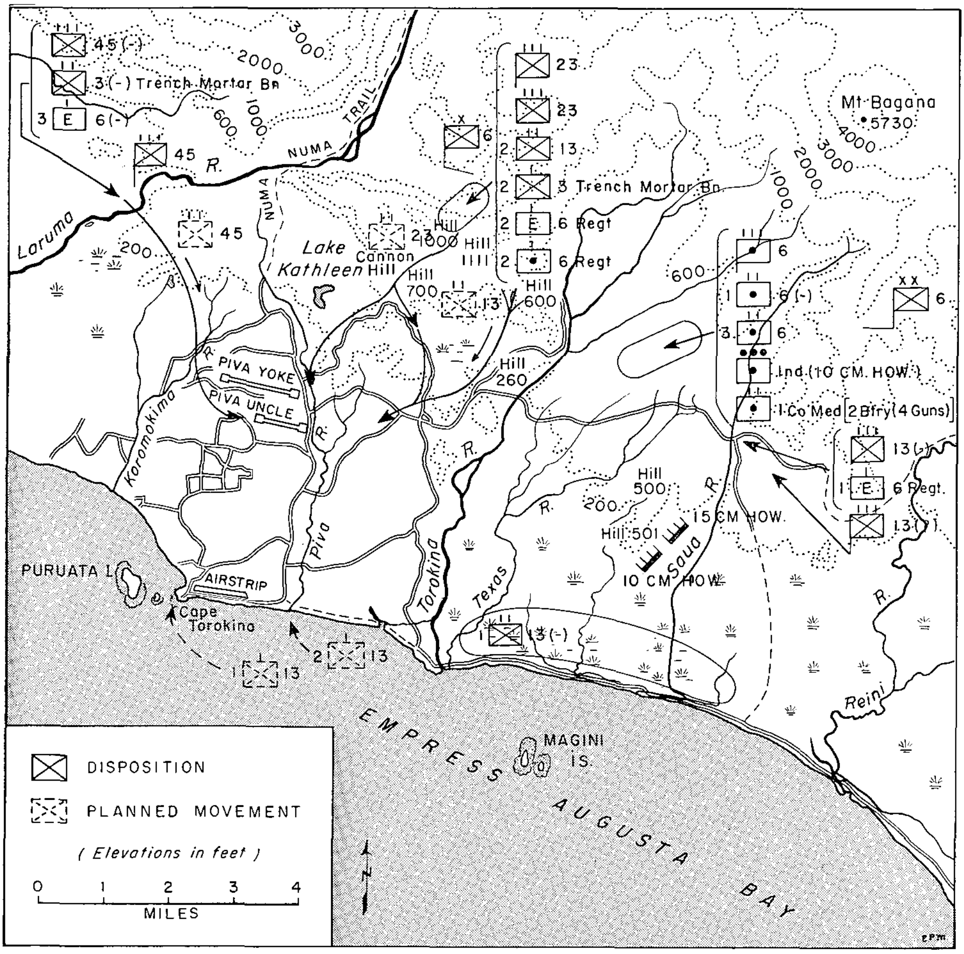


FIGURE 159.—Situation map. Disposition of principal enemy units, 29 February 1944.

The enemy forces faced great difficulties of transportation in the maneuvering of various units, especially heavy artillery, into positions favorable for attack. This had to be accomplished over the most rugged type of terrain at great expenditure of manpower. Finally, they attacked with almost no air support.

Description of the Weapons Commonly Employed by the Japanese [3]

In the period under study, Japanese weapons accounted for 1,569 casualties, including killed and wounded. Table 57 is a breakdown of the type of Japanese weapons responsible for 1,569 Allied casualties.

Estimates based upon captured weapons indicate that the ratio of 6.5 mm. (caliber .256) to the 7.7 mm. (caliber .303) rifle was approximately 4 to 1.

[3] A complete description of Japanese ordnance is contained in chapter I, pp. 4–35.

TABLE 57.—*Japanese weapons responsible for 1,569 Allied casualties*

Type of weapon	Allied casualties	
	Number	Percent
Mortar	659	42. 0
Rifle	393	25. 1
Grenade	205	13. 1
Machinegun	151	9. 6
Artillery	151	9. 6
Miscellaneous	10	. 6
Total	1, 569	100. 0

Furthermore, of the smaller caliber (6.5 mm.) weapon, roughly 90 percent were "long," 7 percent "short," and 3 percent "medium" types.

The almost complete absence of muzzle flash in the Model 38 (1905) is a characteristic commented upon favorably by U.S. soldiers. Since the latest Japanese rifle, Model 99, did not possess this feature, it was apparently considered unimportant by the enemy.

Most commonly employed by the enemy at Bougainville, in a ratio of approximately 4 to 1, were the Model 96 (1936) 6.5 mm. light and the Model 92 (1932) 7.7 mm. heavy machineguns. Extremely rare was Model 11 (1922) 6.5 mm. light machinegun ("Nambu Keiki") among the 200 captured machineguns. Closely resembling the British Bren light caliber .303 model, the Model 96 (1936) 6.5 mm. light machinegun was considered an excellent weapon by American officers.

Wounds ascribed to the mortar at Bougainville in many instances were actually produced by the grenade discharger. Mistakenly called the knee mortar, this weapon, because of its accuracy and efficiency, had earned the respect of the American combat troops and was more feared than any other Japanese weapon. If the "knee mortar" was grouped with the other types of captured mortars, it was found to constitute approximately 90 percent of the total. Among the conventional mortar types, the ratio of the 81 mm. to the 90 mm. was about 3 to 2. A total of 96 mortars were captured, only one of which was the 90 mm. Model 97 (1937).

Because it could be thrown by hand, fired from a grenade discharger, or used as a rifle grenade, Model 91 (1931) hand grenade, "Kyuichi Shiki Shuryudau," was a useful, versatile, and frequently employed weapon. Model 97 (1937) hand grenade was similar to Model 91 except that it had no propelling charge and could not be fired from a grenade discharger. It was carried by all Japanese frontline troops but was said to have poor fragmentation, the fragments being small and of short range. The effective range from the burst was estimated at 5 yards and the danger zone, 30 yards.

In the plan to neutralize and seize the three Torokina airfields, the artil-

lery support was the most extensive yet employed by the enemy in the South Pacific. The Japanese were able to transport a considerable number of heavy weapons through dense jungle and over exceedingly rough terrain to positions overlooking the U.S. perimeter. Assuming all units at full strength, an order of battle indicates that the maximum number of weapons available to them was 136. Actual observation suggested the presence of approximately 40 or 50 pieces.

With the exception of the 10 and 15 cm. pieces, all weapons were of pack type and were undoubtedly carried by hand. Possibly the 150 mm. howitzers may have been dismantled also, as some of these were reported on Mount Bagana. These weapons were brought by water to Koaris and thence by road to the vicinity of Hills 500 and 501. Limited use of horses was reported on the Kahili-Empress Augusta Bay track. Apparently there was no serious shortage of ammunition by Japanese standards, fire having continued intermittently from some positions for 3 weeks. Considerable quantities of ammunition were generally found with the captured weapons.

Principal targets were the airstrips, supply and command post areas, road junctions, and the tank areas. Massing of fire was not utilized and gunfire seemed independent. The heaviest concentration occurred in the early morning and evening hours. On 23 March, in less than 2 hours, 70 rounds fell on the Piva airfields. After the first 2 days of attack, during which some parked planes were destroyed, rarely in a single day did more than five or six shells fall on these same airfields. Difficulties inherent in jungle warfare precluded the use of artillery in close support of attacking Japanese infantry. For this purpose, the Japanese relied principally upon 90 mm. mortar fire.

The Japanese employed at least thirty-five 75 mm. guns, Model 41 (1908) and Model 94 (1934), the former predominating. These pieces were situated north and northeast of the perimeter. Four 150 mm. howitzers were located on the northeast and east and two 105 mm. howitzers on the east near Hill 501. Mortar fire received was principally from the north and northwest sections. The greatest concentration of fire in any one day was 200 rounds. In contrast to the experience during the weeks after the landing in November, the proportion of "duds" was remarkably low. Observers were able to identify by type of burst or by duds about 1,300 rounds received. Of these, 885 were 75 mm. shells and 130 were 150 mm. shells. Many types of artillery weapons were captured. The five most commonly encountered models will be described briefly.

Model 94 (1934) 37 mm. gun was designated "Kyuyon Shiki Sanjunana Miri Ho," and commonly called Sanjunana Miri Ho. It could be used both as an AT (antitank) and antipersonnel weapon, employing AP (armor-piercing), HE (high explosive), and shrapnel ammunition. This gun had a long, slender barrel measuring 66.5 inches in length. The effective range was 2,500 yards and the maximum range 5,000 yards. The total weight of the weapon in action was 714 pounds. The effective burst of the HE shell was said to be 10 yards with a zone of danger extending about 75 yards. Fragmentation tests

revealed that the 560 grams of metal in the shell broke into 490 fragments. Only 143 of these fragments were classified as lethal (average weight of lethal fragment being 3.1 grams).

The Model 92 (1932) 70 mm. howitzer (Battalion Gun), "Kyuni Shiki Hoheiho" was a horse-drawn infantry support howitzer. It weighed 468 pounds and could be handled by a 10-man section. It had an effective range of 1,500 yards and a maximum range of 3,000 yards. The estimated effective range of burst was 20 yards, and the area of danger was 200 to 300 yards.

Issued for use as an infantry regimental gun, the Model 41 (1908) 75 mm. mountain (infantry) gun was originally used as a field artillery pack gun. The effective range of this weapon was 2,100 yards, and it fired both HE and AP shells. With the long, pointed shell, its maximum range was 7,675 yards and with the ordinary shell, 6,575 yards. The total weight was 1,200 pounds. Its muzzle velocity was listed as 1,200 f.p.s. (feet per second). The shell had a probable effective burst of 20 yards with a danger zone of 300 feet.

The Model 96 (1936) 150 mm. mobile field howitzer has a range of 13,200 yards. The effective range of the shellburst was said to be 50 yards with an area of danger of 500 yards. The effect produced was that of blast and fragmentation.

The Model 98 (1938) 20 mm. AA/AT (antiaircraft, antitank) machine cannon was an all-purpose weapon. It was gas operated and semiautomatic or full automatic. The ammunition for this weapon was HE, tracer, and AP and was fed by a 20-round box magazine. This weapon was very maneuverable, weighing without wheels 836 pounds. The rate of fire was 120 rounds per minute. The muzzle velocity was 2,720 f.p.s. and the maximum ranges, horizontal 5,450 and vertical 12,000 feet.

A list of Japanese rifles, machineguns, mortars, grenades, and artillery weapons captured on Bougainville follows.

Nomenclature

Model 38 (1905) 6.5 mm. Rifle (Long)[1]
Model 38 (1905) 6.5 mm. Rifle (Short)
Model 97 (1937) 6.5 mm. Snipers Rifle
Model 38 (1905) 6.5 mm. Rifle (Medium)
Model 44 (1911) 6.5 mm. Cavalry Carbine
Model 99 (1939) 7.7 mm. Rifle [1]
Model 11 (1922) 6.5 mm. Light Machinegun ("Nambu")
Model 96 (1936) 6.5 mm. Light Machinegun
Model 99 (1939) 7.7 mm. Light Machinegun
Model 92 (1932) 7.7 mm. Heavy Machinegun [1]
Model 97 (1937) 81 mm. Mortar [1]
Model 94 (1934) 90 mm. Mortar [1]
Model 97 (1937) 90 mm. Mortar
Model 89 (1929) 50 mm. Grenade Discharger ("knee mortar")

Nomenclature

Model 97 (1937) Grenade [1]
Model 91 (1931) Grenade [1]
Model 23 (1923) Boobytrap Grenade [1]
Model 94 (1934) 37 mm. Gun
Model 1 (1934) 47 mm. Gun
Model 92 (1932) 70 mm. Howitzer (Battalion Gun)[1]
Model 41 (1908) 75 mm. Mountain (Infantry) Gun (or Regimental Gun)[1]
Model 94 (1934) 75 mm. Mountain Gun
Model 91 (1931) 105 mm. Light Field Howitzer
Model 96 (1936) 150 mm. Mobile Field Howitzer [1]
Model 97 (1937) 20 mm. AT Rifle
Model 98 (1938) 20 mm. AA/AT Machine Cannon

[1]Models most frequently employed.

BOUGAINVILLE CAMPAIGN DURING SURVEY PERIOD (15 FEB.–21 APR. 1944)

The Allied beachhead was established during the first week of November 1943. The period before the Battle of the Perimeter was characterized by consolidation of the defenses of the airfields which were being used for attacking enemy installations in the Bismarck Archipelago and on Bougainville. By 15 February, the airstrips were completed and the perimeter established with the 37th Division on the left flank and the Americal Division on the right flank. From 15 February to 8 March, the perimeter defense was strengthened, and an extensive system of roads was further developed within the perimeter. During this period, patrols made contact with enemy forces moving into position north and east of the perimeter. Some artillery installations were discovered, and strong enemy positions were noted on Hills 1000, 1111, and 600 east of the Torokina River mouth (fig. 159). However, during this period, contact with the enemy was limited to patrol skirmishes and an occasional bombing raid at night.

The Battle of the Perimeter extended from 8 March to 24 March. The Japanese had laid plans for this offensive sometime around the turn of the year. Allied intelligence obtained information that the enemy attack was to be launched on 8 or 9 March, thereby permitting ample preparation for defense of the perimeter.

Enemy plan.—The three infantry regiments were to leave their respective lines of departure following an artillery barrage. This barrage was to commence at 0430 Y-day from the main strength of the *6th Artillery Regiment* (fig. 159) located near Blue Ridge (mountain guns) and the medium field artillery (10 and 15 cm. field pieces) deployed near Hill 500. It appears that the *45th Infantry* was to constitute the main thrust and was to strike Allied lines near the point where the Piva-Numa-Numa Road enters the perimeter (129th Infantry sector). Simultaneously, the *23d Infantry* was to launch its attack from approximately 1,000 yards northeast of Hill 700 with the *3d Battalion* on the left and the *2d Battalion* on the right and the *1st Battalion* in reserve. By the end of Y-day, the *3d Battalion* was to have captured Hill 700 and the *2d Battalion* was to have occupied Cannon Hill. These heights overlooked the Piva airstrip, and the main strength of the *23d Infantry* was to have attacked the strip from the east while the *45th* attacked from the west. The *13th Infantry* was to attack Hill 260 and then join with elements of the *23d Infantry* to proceed in the general direction of the airstrip.

The enemy's Torokina operation began on 8 March with preliminary artillery fire directed mostly on the Piva airstrips. Blue Force counterfire against hostile positions located in the general areas of Hills 1111 and 501 began immediately. The main Japanese drives began under the cover of darkness during the night of 8 March and the morning of 9 March at the three points on the perimeter. In the east sector patrol, contacts and fire fights took place in the vicinity of Hill 260. To the north on Hill 700, the Japanese

infiltrated through Allied lines and occupied the northwest slope of the hill. Blue Force counterattack reduced the Japanese positions, and the perimeter was reestablished. In the northwest sector, several fire fights occurred. The Japanese had occupied strong points on Hill 260 and severe fighting resulted in retaking these points, but by 11 March two Blue Force companies occupied Hill 260 with the exception of strong points on the southeast slope. Another attack on the northern sector was repulsed. Meanwhile, preparations for an enemy drive from the northwest continued. On 12 March, three major attacks from the northwest near the Numa-Numa Trail placed the Japanese within the U.S. perimeter. American tank-infantry teams reestablished the lines next day. The same Blue Forces on Hill 700 received and repelled the third attack on that position. On 15 March, another attempt was made by the Japanese to break through the sector held by the 129th Infantry. Tank-infantry counterattack again restored the perimeter. The next strike by the enemy was again from the northwest near the Piva-Numa-Numa Trail on 17 March. Although a 75-yard penetration was made for the third time, tanks and infantry drove the enemy back. For a week, the Japanese remained relatively quiet, regrouping their forces opposite the northwest sector of the perimeter. Smaller holding forces which were dug in were contacted on the other sectors. On 24 March, after a feeble attempt at laying an artillery barrage, the Japanese struck toward the Piva airstrips once more, penetrated the 129th Infantry lines, and again were driven back, losing 300 men and a field gun. On each occasion when penetration was made, the enemy succeeded in occupying pillboxes within the U.S. perimeter only to be dislodged with heavy losses.

The Japanese did not again attack in force after the repulse on 24 March and began a general withdrawal. Hill 260, however, was not evacuated by the enemy until 28 March. From 28 March to 22 April when this study was completed, contact with the enemy was limited to a few fire fights, patrol skirmishes, and occasional shelling of the airstrips. There were 5,522 Japanese dead counted between 8 March and 22 April. This, however, did not include all areas subjected to U.S. artillery fire.

Battle of the Perimeter

Operations on Hill 260[4]

The original garrison on Hill 260, a reinforced platoon from Company C, was attacked by a Japanese force of undetermined size at dawn on 10 March. The enemy generally occupied the area south of the outpost tree (fig. 160), and, from this date until the termination of the battle, the Japanese tried to increase their garrison and improve their positions on that side of the hill in order to secure observation for an all-out attack on the main line of resistance.

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[4] Report, Lt. Col. Wm. J. Mahoney, Executive Officer, Headquarters, 182d Infantry, Americal Division.

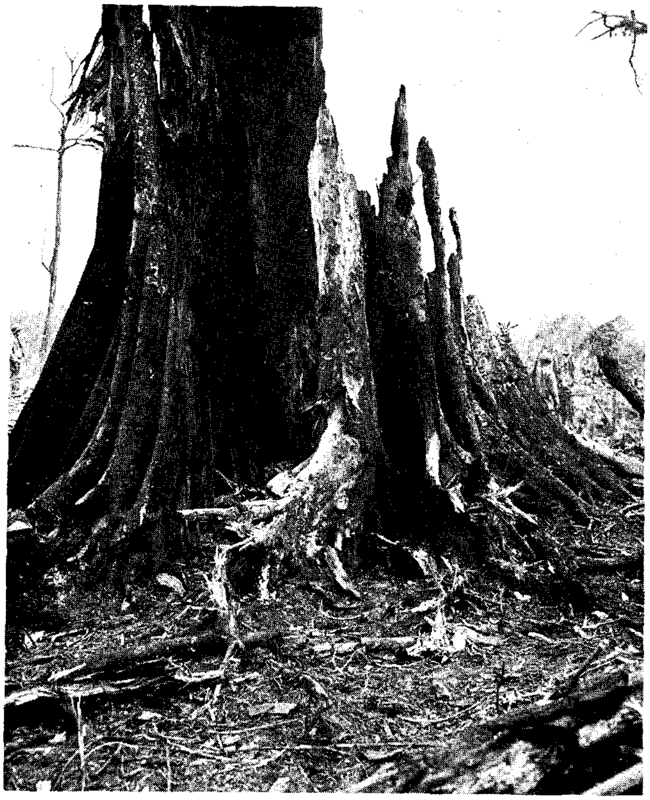

FIGURE 160.—Focal point of entire Hill 260 battle. Banyan tree used as an Americal Division artillery spotting post. In the 20-day fight for the hill, 541 Japanese were killed.

The terrain was that of an elongated hill with moderately steep sides covered by rain jungle. The outpost tree (fig. 160), around which the heaviest fighting occurred, was one of a common variety of trees on Bougainville, the roots of which plus excavation make a very strong defensive position (fig. 161).

After the initial attack, the Japanese held the south end of Hill 260. They greatly increased the force which had made the original attack because they beat back the Allied attempt to storm the northwest, southwest, and southeast ridges of the hill during the period 11–17 March. Apparently, their main route of supply and evacuation was down the steep east side of the hill, then north clinging to the east side of the west bank bluff overlooking the Torokina River. This route was well concealed and in defilade and difficult to reach by fire. After the initial engagement, reinforcements were sent to secure the north side of Hill 260. The establishing of a perimeter there and the continual pressure on the Japanese positions completely neutralized the effect of the offensive action taken by the Japanese. The possession of Hill

U.S. Army photo

FIGURE 161.—Banyan trees are common in the jungle on Bougainville and offer excellent protection. The outpost tree on Hill 260 was of this variety.

260 by the enemy would have jeopardized a considerable portion of the Allied main line of resistance.

From the outset, the problem on Hill 260 was one of ejecting the Japanese from the south end of the hill. Their positions were well dug in (fig. 162), and the various American assaults to take the hill were turned back with heavy casualties. Artillery and mortars were useful in blasting Japanese positions in the general area, but because of the proximity of American troops, prepared fires could not be used on the Japanese positions just outside the U.S. perimeter. Artillery was effective on the exposed southwest slope, and after a week's fighting the Japanese were pretty well removed from that area (fig. 163). But those in defilade on the southeast slope dug in and countered every American move. Various means were used to force the Japanese from their dugouts during the closing 10 days of the battle. It was obvious at that time that the Japanese garrison was considerably reduced in numbers although there was no corresponding lessening of firepower. Flamethrowers and gasoline ignited with thermite grenades reduced a few pillboxes (fig. 164). As late as the morning of 28 March, Japanese were seen near pillboxes on the southeast slope. On the morning of 28 March, three patrols were sent around the base of the hill to fire on the Japanese. When there was no fire, the Allied patrols investigated and found that the Japanese had evacuated. At 1246, 28 March, Hill 260 was secured. On the morning of 30 March, the 2d Battalion, 182d Infantry, was replaced on the hill by 1st Battalion, 24th Infantry.

U.S. Army photo

FIGURE 162.—Jungle growth on Hill 260, showing protection afforded by trees.

FIGURE 163.—Hill 260 being shelled by Americal Division artillery fire, on 19 March. The firing continued for several hours at the end of which time it was believed that all enemy resistance had been neutralized. Note partial destruction of jungle growth.

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FIGURE 164.—Enemy pillbox on Hill 260. The dense jungle growth has been entirely cleared away by artillery fire.

American forces engaged.—Companies B, E, F, G, and H plus one platoon of Company K, 182d Infantry, and Company G, 164th Infantry, actively took part in the action on the hill. All other companies in the regiment were in general support plus A and B Companies, 57th Engineer Combat Battalion; 246th and 247th Field Artillery Battalions; 82d Chemical Battalion—total, 1,350 men.

Japanese forces engaged.—Elements of the *13th* and *23d Infantry Regiments*, both part of the *6th Division*, were identified as taking part in the battle for Hill 260. It was estimated that 1,400 Japanese were involved in this action.

Table 58 lists the casualties sustained by the 1,350 U.S. troops engaged on Hill 260.

In comparison to the other two main thrusts by the enemy on the perimeter, there was more offensive action by U.S. troops on Hill 260. The enemy in the initial attack had captured and had managed to defend the outpost tree which was the focal point on the hill. Furthermore, the character of the terrain lent itself readily to defense and prevented the effective use of tanks.

The heaviest casualties were in the 182d Infantry with 800 troops involved (table 59).

Estimates of Japanese killed and wounded were difficult to make because of their practice of carrying away and burying their own dead. A total of 212 Japanese bodies were found by U.S. troops on Hill 260, and the Americal Division G-2 (intelligence) listed 541 Japanese as the total killed. The ratio of Japanese to U.S. troops killed was 7.6 to 1. In addition, many wounded

were seen going to the rear, and it is believed an entire battalion plus a number of supporting troops were virtually wiped out. The heaviest fighting occurred during the period 10–14 March and, as indicated later by prisoner-of-war reports, this engagement broke up the initial attack of the entire Japanese *13th Infantry Regiment* on the Bougainville perimeter.

TABLE 58.—*Distribution of 713 casualties among 1,350 U.S. Army troops engaged on Hill 260, by category*

Category	Number of casualties			Percent of—	
	Officers	Enlisted men	Total	Total casualties	Total troops engaged
Killed-in-action	8	63	71	9.9	5.2
Wounded:					
Seriously	9	204	213	29.9	15.8
Slightly	37	370	407	57.1	30.2
Missing-in-action	4	18	22	3.1	1.6
Total	58	655	713	100.0	52.8

TABLE 59.—*Distribution of 426 casualties among 800 men of the 182d Infantry engaged on Hill 260, by category*

Category	U.S. casualties		Total troops engaged
	Number	Percent	
			Percent
Killed-in-action	63	14.8	7.9
Wounded:			
Seriously	106	24.9	13.2
Slightly	256	60.1	32.0
Self-inflicted	1	.2	.1
Total	426	100.0	53.2

Operations on Hill 700 [5]

The terrain here was mountainous but mostly second growth (fig. 165) rather than virgin jungle. The sides of the ridges were very steep (fig. 166) and at one point of the assault were almost precipitous. The action by U.S. troops was largely defensive but did involve the recapture of certain positions into which the Japanese had infiltrated. A one-way road leading along behind Allied lines for a time was under enemy fire (fig. 167), necessitating a difficult carry (fig. 168) for the litter bearers of more than a thousand yards.

[5] Report, After Action Operations, 37th Infantry Division, pt. II, G–3 Operations Narrative, 8 Nov. 1943–30 Apr. 1944.

U.S. Army photo

FIGURE 165.—Partially cleared jungle growth on Hill 700. Through this draw, the Japanese made their approach to the hill.

FIGURE 166.—Precipitous hillside off the perimeter road. Grenades were rolled down this bank causing many casualties.

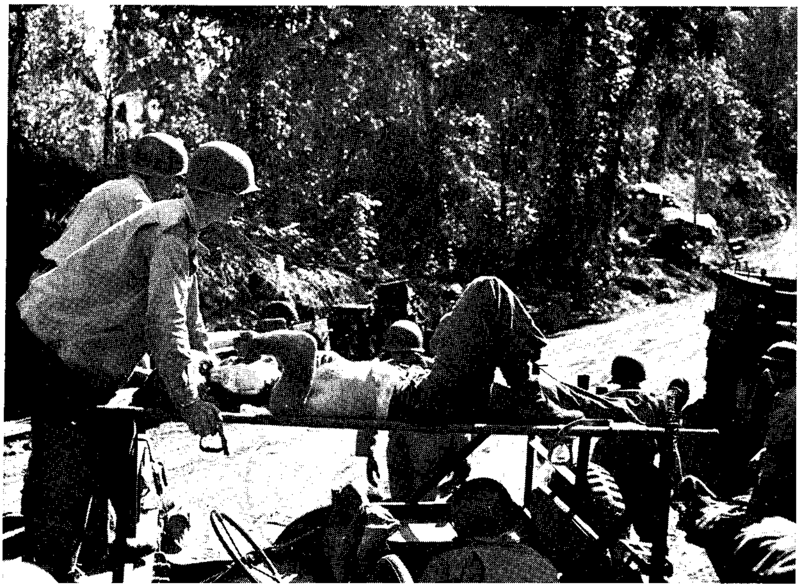

FIGURE 167.—Wounded being transferred from halftrack to jeep. Halftrack was used because road was under fire.

FIGURE 168.—Wounded soldier being helped down the side of Hill 700 by two medical aidmen.

On the morning of 8 March, the Japanese attack began with some artillery and spasmodic small arms fire which continued throughout the day. During the night of 9 March, boobytraps warned of attack followed by hostile fire from mortars and rifles. At dawn, it was found that at least one company of Japanese had occupied the north slope and crest of Hill 700 and had penetrated the Allied line to a depth of 75 yards over a 100-yard front. During the day, a counterattack by the 1st and 2d Battalions of the 145th Infantry regained several pillboxes on the south slope of the hill. One tank was used with fair success along the road which was under fire. On 10 March, the enemy retained possession of the crest of the hill in spite of continued ground action. Efforts to reach the Japanese positions on Hill 700 by engineer "polecharges," bangalore torpedoes, and bazookas were without avail and resulted in numerous casualties due to the excellent Japanese field of fire.

At 1700 hours on 10 March, a determined attack was made by U.S. forces who, in spite of intense enemy light and heavy mortar and artillery fire (fig. 169), succeeded in driving the enemy from the crest of Hill 700. Japanese concentrations coming up to reinforce this area were subjected to heavy bombing and artillery fire which was very effective. On 11 March at daylight, the enemy made a general assault on Cannon Hill held by the 3d Battalion of

U.S. Army photo

FIGURE 169.—Japanese 75 mm. gun emplacement on Blue Ridge that was used by the enemy in their attack on Hill 700. Interior view; note the large window.

the 145th Infantry. The attack was repulsed with the exception of one pillbox gained by the enemy on Hill 700 (fig. 170). Japanese losses were reported as enormous with the enemy assault wave attacking over piles of their own dead. On 12 March after severe fighting, U.S. forces succeeded in driving the enemy from Hill 700. A total of 399 Japanese dead were counted within the wire on the crest and on the forward slope of the hill. On the night of 13 March, the enemy again attacked in the draw west of Hill 700. Searchlights were used successfully to reflect light from the overhanging clouds, and the attack was repulsed. After this date, only intermittent contact was made with the enemy in this area.

FIGURE 170.—Enemy dead killed while defending their position in a pillbox on Hill 700.

During the engagement on Hill 700, there were approximately 2,600 U.S. troops involved. Table 60 summarizes the various types of casualties among the 519 total casualties.

A total of 2,219 (719 counted, 1,500 estimated) Japanese were killed in action during the engagement of Hill 700. For this encounter, the ratio of U.S. dead (KIA plus DOW) to Japanese dead was 1 to 36.

The large number of enemy dead estimated rather than counted was due to the enemy custom of burying several bodies in one grave and also to the large number killed by U.S. bombing and artillery fire behind the lines, making it impossible to obtain an immediate count.

TABLE 60.—*Distribution of 519 casualties among 2,600 U.S. troops engaged on Hill 700, by category*

Category	Casualties		Total troops engaged
	Number	Percent	
			Percent
Killed-in-action	45	8.7	1.7
Wounded-treated-died	16	3.1	.6
Total	61	11.8	2.3
Wounded living:			
Returned to duty	215	41.4	8.4
Hospitalized	243	46.8	9.3
Total	458	88.2	17.7
Grand total	519	100.0	20.0

Operations on 129th Infantry sector[6]

The terrain here was fairly flat (fig. 171) covered with second growth and provided fair ground for tank maneuvers. The action here was characterized by temporary withdrawals of U.S. troops from forward positions under the pressure of Japanese attacks followed by highly effective tank supported counterattacks (fig. 172).

On 6 March, there were numerous patrol contacts and clashes with superior Japanese forces advancing along the Laruma River, and Allied outposts were forced back. The main attack by the Japanese *45th Infantry* was launched on the morning of 12 March and succeeded in penetrating Allied wire and in occupying several pillboxes, some of which were retaken by counterattack. Again, in the early morning of 13 March, the enemy succeeded in taking six more pillboxes, and counterattacks supported by tanks resulted in retaking all but two pillboxes (fig. 173). The Japanese were attacking very strong positions in relatively open terrain, and their losses were heavy, estimated at 350–500 dead on this day, compared with 2 killed and 10 wounded in the 129th Infantry sector. The next day, 14 March, was a relatively quiet day during which Allied wire was repaired under cover of the tanks. On 15 March at 0400 hours, the Japanese again attacked and, after heavy fighting, penetrated to a depth of 100 yards over a 1,000-yard front. A tank-supported counterattack failed to dislodge the enemy who had now brought in at least one 77 mm. field gun. A second counterattack, supported by tanks and by a heavy concentration of artillery, reestablished the Allied line. Spasmodic fire occurred

[6] See footnote 5, p. 299.

FIGURE 171.—A cleared field of fire in front of the 129th Infantry sector.

U.S. Army photo

FIGURE 172.—Light tank of the 754th Tank Battalion. This tank was in action against the Japanese at Company G, 129th Infantry, 37th Division perimeter. The cleared area in front of perimeter greatly facilitated the use of tanks.

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FIGURE 173.—Soldiers of Company F, 129th Infantry, 37th Division, crawling up to barbed wire. Japanese were just in front of and to left of the wire and occupied the American pillboxes to the left and to the right (not shown in picture). American troops were surrounded until tanks were called upon to knock out the enemy.

on 16 March, but on 17 March at 0400 hours the enemy again attacked, breaching Allied wire to a depth of 75 yards where the attacks stopped and the enemy dug in. Prisoners' statements indicated that Allied artillery had taken a huge toll in the support and reserve units. Allied artillery continued a heavy harassing fire (fig. 174), and except for sporadic fire fights the sector was relatively quiet until 24 March when shortly after midnight the Japanese began to infiltrate. By daylight, the enemy had penetrated 300 yards (fig. 175). During the day, there was heavy hole-to-hole fighting and tank-supported counterattacks (fig. 176) which regained control of the high ground. During the latter fighting, the Japanese losses were large (fig. 177), 310 dead were counted within Allied wire compared to U.S. losses of 16 killed and 42 wounded. The artillery placed an extremely heavy concentration in front of Allied lines (fig. 178) following which only sporadic attempts to penetrate Allied wire occurred.

Table 61 gives a breakdown of the 450 casualties that were sustained by the 1,850 U.S. troops engaged on the 129th Infantry sector.

Approximately 4,300 Japanese troops were engaged on the 129th sector up to 16–17 March when an additional 600 men were brought into the area. The actual count of enemy dead was 2,373. The ratio of U.S. dead (KIA plus DOW) to Japanese dead was 1 to 30.

U.S. Army photo

FIGURE 174.—An area devastated by U.S. artillery shell fire.

FIGURE 175.—Scene at area command post during action of Japanese infiltration of 2d Battalion, 129th Infantry, 37th Division. Reinforcing troops of Company A are in prone positions as an enemy machinegun opens fire. Tanks in background were called upon to knock out enemy positions. Burning jeep is the result of a Japanese grenade.

FIGURE 176.—Scene of a General Sherman medium tank and infantrymen attacking Japanese positions along the perimeter of 129th Infantry, 37th Division.

FIGURE 177.—Japanese killed on the perimeter of Company F, 129th Infantry, 37th Division. The enemy dead were hit by so many missiles it was impossible to determine cause of death.

U.S. Army photo

FIGURE 178.—Japanese foxholes under bank of draw in 129th Infantry sector. Note how jungle was cleared by artillery fire.

TABLE 61.—*Distribution of 450 casualties among 1,850 U.S. troops engaged on 129th Infantry sector, by category*

Category	Casualties		Total troops engaged
	Number	Percent	
			Percent
Killed in action	64	14. 2	3. 5
Wounded-treated-died	14	3. 1	. 7
Total	78	17. 3	4. 2
Wounded living:			
Returned to duty	160	35. 6	8. 6
Hospitalized	212	47. 1	11. 5
Total	372	82. 7	20. 1
Grand total	450	100. 0	24. 3

Comment on Relatively Large Number of Japanese Casualties

Since one of the purposes of this study was to make observations on the relative lethal effects of weapons, the great disproportion between enemy and U.S. casualties deserves some comment. It is estimated that the enemy had 8,527 killed in action out of 10,000 troops involved in combat, as contrasted

to 210 killed (180 KIA plus 30 DOW) out of 5,800 U.S. troops involved. This is a ratio of 23.9 Japanese for each 1 of U.S. forces killed.

The approximate time for the Japanese attack was known, as well as the most likely points of attack. Consequently, the enemy attacked against extremely well prepared positions. United States supplies of ammunition were abundant and easily accessible to the front by an excellent system of roads. The concentration of firepower, especially artillery and mortar, was intensive. United States artillery concentration on Japanese reinforcements moving over restricted jungle tracks was particularly effective. United States forces had complete control of the air making it easy to observe, as well as to bomb, enemy troop concentrations. The limited supply of enemy artillery and ammunition had to be transported under great difficulties over the most rugged terrain. Furthermore, as in other campaigns in the South Pacific, enemy artillery was never used in concentration as judged by U.S. standards. Whenever the Japanese broke through Allied lines, which they did repeatedly, they never appeared to have sufficient reserves to follow up the advantage. There is evidence that the concentration of U.S. artillery fire on Japanese reinforcements prevented the accumulation of any effective body of troops.

On Hill 260, the ratio of Japanese dead to U.S. dead was 8 to 1. This was the most favorable ratio for the Japanese in any of the three sectors. The enemy had taken the hill very early and acquired the advantage of the terrain. Consequently, the action of U.S. troops was mostly offensive under the disadvantage of retaking a hill in which the enemy occupied well dug-in positions. The terrain prevented the use of tanks, and the proximity of the lines limited the use of U.S. artillery.

On Hill 700, the ratio of Japanese dead to U.S. dead was 36.3 to 1. While it was necessary here, also, to retake the crest of the hill, the major part of U.S. action was defensive in well-prepared positions. The enemy approach to this sector was limited because of the terrain, making artillery concentrations on their reinforcements highly effective and accounting for the greater number of enemy dead. On reaching the vicinity of U.S. lines, the enemy attacked up steep slopes in great concentration.

On the 129th sector, the ratio of Japanese dead to U.S. dead was 30 to 1. Here the approach for the enemy via the Numa-Numa Trail was easier, and the terrain permitted attack on a wider front. The terrain was also favorable to the use of tanks, and these were highly effective in retaking positions lost after the enemy had exhausted the force of their initial impact and their reserves had been disrupted by U.S. artillery. On this sector, also, the enemy attacked in great concentration on a narrow front against strongly prepared positions. Against these concentrated attacks, the use of canister-type ammunition was highly effective.

Control of the air, the use of tanks, and superior firepower in defensive positions, in addition to the greater and more effective concentrations of artillery fire, were the chief factors accounting for the large number of the enemy dead.

DISPOSITION OF BATTLE CASUALTIES AND ANATOMIC DISTRIBUTION OF WOUNDS

In this chapter, the term "battle casualty" is used to designate only those combatants who were killed or wounded by weapons. All deaths or injuries produced by other agents, such as falling trees, motor vehicle accidents, or others of a similar nature have been excluded. The total number of casualties includes all those wounded both by Allied and enemy weapons. Wounds caused by Japanese weapons and those resulting from U.S. weapons have been separated and are discussed under separate sections. It was impossible to ascertain which of the self-inflicted wounds were due to the soldiers' willful misconduct and which were accidental. These wounds are included and discussed in the section on U.S. weapons. It is known that 12.3 percent of the total casualties were produced by U.S. weapons. The actual percentage, however, may be slightly greater, for it is known that the enemy did use some U.S. captured weapons, particularly rifles and grenades.

There were 2,335 battle casualties. Of these, 547 (23.4 percent) were lightly wounded and were returned to duty immediately from the battalion aid or collecting stations. These 547 casualties are included in the initial total for the sake of completeness, for it was assumed that reports of casualty studies in other armies are based on computations which also include this group of minor wounds. However, in the remainder of the study, these patients have been excluded, because of the insignificant disability entailed by their injuries. Therefore, this study was based primarily on 1,788 casualties who were killed in action or who sustained wounds which necessitated hospital treatment. The term "hospital" includes two augmented clearing stations. The majority of patients returned to duty in the first echelon [7] were treated in these clearing stations. With few exceptions, all patients who were returned to duty in the first echelon left the hospital within 30 days. Those patients in a hospital of the rear echelon, who were not evacuated to the United States, were usually returned to duty within 120 days.

Since no exact definition for the term "killed in action" [8] has been established, an arbitrary standard was selected. In this study, KIA (killed in action) includes only those killed instantly, those found dead, and those who were mortally wounded and died shortly thereafter. Reports from division surgeons invariably contained a greater number of KIA than are found in this study. Explanation for this discrepancy is apparent and lies in the fact that the battalion surgeon frequently included, among the KIA's, patients who were initially seen alive but who were known to have died later. In this particular campaign, because of the close proximity of hospitals to the front, a large number

[7] In this chapter, "first echelon" is defined as the beachhead perimeter on Bougainville Island.—J. C. B.

[8] The usual definition is: Wounds directly due or attributable to enemy action which result in death before the casualty is admitted to a medical installation or receives treatment from a medical officer.—J. C. B.

of casualties are included under WIA (wounded in action),[9] who perforce, under less favorable circumstances, would have been classified as killed in action.

Table 62 gives a breakdown of the Bougainville casualties during the survey period and the general disposition of the WIA. It may be seen that the 395 dead (320 KIA and 75 DOW) constitute 16.9 percent of the total casualties. Thus, there was approximately one battle death (KIA plus DOW) among every six casualties (WIA, including DOW, plus KIA). Nearly 70 percent of all casualties were returned to duty within the theater and, of the 1,940 living wounded, 1,622 (83.6 percent) were returned to duty. However, 547 of these were returned to duty from a first aid post and did not require hospitalization. These soldiers had very minor wounds and were not lost to battle. Since the incapacitating effect of weapons on this group was negligible, they were eliminated from the remainder of this study, leaving 1,788 casualties who were killed or whose wounds were of such severe degree that they were lost to the battle. Using this criterion, there was approximately one battle death (KIA plus DOW) among every four and a half casualties (WIA, including DOW, plus KIA). The WIA (including DOW)/KIA ratio was 4.6 : 1. Those who died and those who were evacuated to the United States were classed as "lost to service" and comprised 30.5 percent of the total casualties.

A study of both the living and the dead is essential in order to gain an accurate and complete picture of the anatomic distribution of wounds produced

TABLE 62.—*Distribution of 2,335 Allied casualties in Bougainville campaign, from 15 February to 21 April 1944, inclusive, by category*

Category	Casualties	
	Number	Percent
Killed-in-action	320	13. 7
Wounded-treated-died	75	3. 2
Total	395	16. 9
Wounded, living:		
Evacuated to United States	318	13. 6
Returned to duty from—		
Aid station	547	23. 4
First echelon hospital	700	30. 0
Rear echelon hospital	375	16. 1
Total	1, 940	83. 1
Grand total	2, 335	100. 0

[9] The usual definition is: Wounds directly due or attributable to enemy action which necessitate admission of the casualty to a medical installation and treatment by a medical officer. This generally includes those who are wounded treated, and died later (died-of-wounds (DOW)) or preferably wounded-treated-died (WTD).—J. C. B.

by various weapons. Although many wound studies have been made on the living, few records are available which analyze the effect of weapons on both the dead and living. In this investigation, data concerning all those who were killed in action as well as those who were wounded in action and died later have been collected and combined with the records of the living wounded.

Information regarding the circumstances of wounding in the living is relatively easy to obtain. Frequently, the facts may be elicited by an interview with the person wounded. However, the information will be still more accurate if checked with an eyewitness. To secure accurate details concerning the dead, however, is much more difficult. Post mortem examinations should be done, of course, whenever possible. Autopsies, however, were limited by the fact that all bodies could not be recovered and also by the fact that some were decomposed when recovered. Unfortunately, rapid deterioration occurs in the tropical climate of Bougainville, and for sanitary reasons the dead must be buried as soon as possible. The dead, when recovered, frequently exhibit wounds other than those which produced death. Wounds inflicted after death were especially common in areas subjected to concentrated artillery or mortar fire. Furthermore, it was often difficult and frequently impossible to identify the lethal weapon from the appearance of the wound or the missiles recovered at autopsy. In many instances, discrepancies were found when the emergency medical tag, hospital record, and post mortem findings were compared. It became apparent, therefore, that the true sequence of events leading to death could be secured only by careful personal questioning of witnesses who saw the soldier killed or who knew personally of the circumstances surrounding his death. By adhering to this method of investigation, a relatively high degree of accuracy was achieved, not only in the records of the dead but also of the living.

All casualties were classified under anatomic regions according to the location of the wound. In many instances, a major wound was accompanied by one or more minor wounds. In this event, the anatomic location of the major wound alone determined the classification. Furthermore, if a single wound among others was responsible for death or disability, the anatomic location of that wound determined the classification. In the classification of the casualties, it became necessary to add to the conventional division by anatomic regions, an additional group which was designated "Multiple Wounds." The term "multiple wounds" is used for those casualties sustaining two or more wounds, either one of which might have been responsible for the soldier's death or for rendering him unfit for action. It was difficult or impossible to classify accurately all casualties who received more than one wound. In many instances, the dead were struck by other missiles after death, under which circumstances it was not possible to decide which of several wounds produced death. In other instances, decomposition of the body made examination unsatisfactory. For these and other reasons, some patients were placed in the multiple wound classification, who probably should have been included properly with those grouped under single anatomic regions. Because of the diffi-

culty in analysis of the "multiple wounded," every effort was made to keep to a minimum the number so classified. Nevertheless, the "multiple wounded" constituted 18.6 percent of the casualties (table 64).

It is desirable in a study of this kind, if possible, to evaluate the influence of various factors on the anatomic distribution of wounds. Particular consideration should be given to the type of action (defensive or offensive), available cover or protection, armor, terrain, and type of weapon and projectile employed. Furthermore, if a true representation of the distribution of wounds is to be established, the data should be derived from a study of the dead as well as the living.

In table 63, the anatomic distribution of wounds in the living and dead in Bougainville is compared with similar wound distributions in the living in two past wars and in World War II. It will be observed that head wounds were more frequent at Bougainville than elsewhere. Perhaps this was due to the relatively close range of rifle fire in jungle warfare. Another discrepancy is observed by comparing the percentage of wounds of the head, chest, and upper extremities in the living. For example, wounds of these regions on Bougainville attained a total of 60.5 percent, whereas the Russians in World War II reported a total of only 48.5 percent.

TABLE 63.—*Comparison of wounds in living wounded of two past wars and World War II with casualties of Bougainville campaign, 15 February to 21 April 1944, inclusive, by anatomic location*

Anatomic location	Living wounded					Bougainville campaign	
	Civil War	World War I		World War II		Living wounded [1]	Dead [1]
		U.S. Army	British Army	U.S. Army	Russian Army		
Head, face, neck	9. 1	11. 4	16. 8	16. 1	9. 1	20. 7	49. 0
Chest	11. 7	3. 6	7. 8	9. 8	11. 4	12. 4	29. 6
Abdomen	6. 0	3. 4	4. 7	5. 6	6. 2	5. 7	16. 3
Upper extremities	36. 6	36. 2	30. 4	28. 2	28. 0	27. 4	. 3
Lower extremities	36. 6	45. 4	40. 3	40. 3	45. 3	33. 8	4. 8
Total	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0	100. 0

[1] Multiple wounds excluded.

Source: Monthly Progress Report, Army Service Forces, War Department, April 1944, Section 7: Health.

With the exception of head wounds, the anatomic distribution of wounds in jungle warfare does not appear to differ greatly from the distribution of wounds reported for other types of warfare. In the absence of available data on other types of warfare, it is difficult to derive an adequate explanation for this high frequency of head wounds. The mortar followed closely by the rifle was the most frequent cause of wounds of the head. Since rifles are used frequently, and at close range, in jungle warfare, it is suggested that the greater

number and accuracy of bullets might account for the high incidence of head wounds. However, no proof can be offered for this hypothesis. The factor of exposure appears to offer no better explanation, since the head is apparently exposed to the same degree in jungle as in other types of warfare. The predominance of lower extremity wounds is accounted for by the high incidence of mortar hits.

Table 64 shows the anatomic distribution (regional frequency) of wounds in the 1,788 Bougainville battle casualties.

TABLE 64.—*Distribution of wounds in 1,788 battle casualties, by anatomic location (regional frequency)*[1]

Anatomic location	Total casualties		Dead		Living	
	Number	Percent	Number	Percent[2]	Number	Percent[2]
Head	384	21.5	144	37.5	240	62.5
Thorax	231	12.9	87	37.7	144	62.3
Abdomen	114	6.4	48	42.1	66	57.9
Extremities:						
Upper	320	17.9	1	.3	319	99.7
Lower	407	22.7	14	3.5	393	96.5
Multiple	332	18.6	101	30.4	231	69.6
Total	1,788	100.0	395	22.1	1,393	77.9

[1] Any casualty with major wounds in more than one anatomic region is cataloged under "Multiple." Therefore total number of wounds is same as total number of casualties.

[2] Percent for dichotomy, dead versus living, by each anatomic location and for total dead versus living.

The anatomic distribution of wounds in the dead (table 65) is in striking contrast to the distribution of wounds in the living (table 66). The low incidence of extremity wounds among the dead is a rough index of the effectiveness of modern surgery, when dealing with wounds which do not involve a vital organ. Multiple wounds hold second place among the dead. Bullets (rifle and machinegun), mostly at close range, caused 58.2 percent of all deaths (table 77), while high explosives (artillery, mortar, grenade, and mine) caused 38.8 percent. A consideration of those who were wounded in action and died later (table 65) indicates that the major problem is encountered in wounds of the abdomen and thorax. These two regions accounted for 65.3 percent of all those who were wounded in action and died later.

An index of the degree of the residual disability may be obtained by a consideration of the number of patients returned to duty or evacuated to the United States (table 66). It should be noted that while the total number of patients in the anatomic divisions varies considerably, the percentage of patients returned to duty in each anatomic region remains remarkably constant.

TABLE 65.—*Distribution of wounds in 395 dead, by anatomic location*

Anatomic location	Total casualties		Killed in action			Died of wounds		
	Number	Percent	Number	Percent [1]	Percent [2]	Number	Percent [1]	Percent [2]
Head	144	36. 5	134	41. 9	93. 1	10	13. 3	6. 9
Thorax	87	22. 0	66	20. 6	75. 9	21	28. 0	24. 1
Abdomen	48	12. 2	20	6. 2	41. 7	28	37. 3	58. 3
Extremities:								
Upper	1	. 2	1	. 3	100. 0			
Lower	14	3. 5	6	1. 9	42. 9	8	10. 7	57. 1
Multiple	101	25. 6	93	29. 1	92. 1	8	10. 7	7. 9
Total	395	100. 0	320	100. 0	81. 0	75	100. 0	19. 0

[1] Percent killed in action or died of wounds by each anatomic location of total killed in action or died of wounds, respectively.
[2] Percent for dichotomy, killed in action versus died of wounds, by each anatomic location and for total killed in action versus died of wounds.

TABLE 66.—*Distribution of wounds in 1,393 living wounded, by anatomic location*

Anatomic location	Total casualties		Returned to duty		Evacuated to United States	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Head	240	17. 2	199	82. 9	41	17. 1
Thorax	144	10. 3	110	76. 4	34	23. 6
Abdomen	66	4. 8	42	63. 6	24	36. 4
Extremities:						
Upper	319	22. 9	243	76. 2	76	23. 8
Lower	393	28. 2	308	78. 4	85	21. 6
Multiple	231	16. 6	173	74. 9	58	25. 1
Total	1, 393	100. 0	1, 075	77. 2	318	22. 8

[1] Percent for dichotomy, returned to duty versus evacuated to United States, by each anatomic location and for total returned to duty versus evacuated to United States.

Table 67 lists the regional frequency of wounds and the disposition of the living wounded in the 1,788 casualties.

Head wounds alone were responsible for 384 or 21.5 percent of all battle casualties. Of the 134 KIA in this group, death resulted from brain injury in 125 and from wounds of the face and neck in 9. In the 10 patients who were wounded in action and died later, 9 sustained brain injuries and 1 a transection of the cervical spinal cord. A more detailed description of these 10 patients will be found in another section under "Treatment of the Wounded." Of the surviving 240 patients, 157 (65.4 percent) were returned to duty in the first echelon.

TABLE 67.—*Distribution of 1,788 battle casualties, by disposition and anatomic location of wounds (regional frequency)*

Anatomic location	Regional frequency	Total casualties		Dead						Living wounded							
				Total		Killed in action		Wounded in action (DOW)		Total		Returned to duty from first echelon [1]		Returned to duty from rear echelon [2]		Evacuated to United States	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
	Percent																
Head	21.5	384	100.0	144	37.5	134	34.9	10	2.6	240	62.5	157	40.9	42	10.9	41	10.7
Thorax	12.9	231	100.0	87	37.7	66	28.6	21	9.1	144	62.3	63	27.3	47	20.3	34	14.7
Abdomen	6.4	114	100.0	48	42.1	20	17.5	28	24.6	66	57.9	19	16.7	23	20.2	24	21.0
Extremities:																	
Upper	17.9	320	100.0	1	.3	1	.3	----	------	319	99.7	175	54.7	68	21.2	76	23.8
Lower	22.7	407	100.0	14	3.5	6	1.5	8	2.0	393	96.5	195	47.9	113	27.7	85	20.9
Multiple	18.6	332	100.0	101	30.4	93	28.0	8	2.4	231	69.6	91	27.4	82	24.7	58	17.5
Total	100.0	1,788	100.0	395	22.1	320	17.9	75	4.2	1,393	77.9	700	39.1	375	21.0	318	17.8

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

In table 68, the head wounds previously summarized (in table 67) are combined with those head wounds which are described later under "Multiple Wounds," making a total of 505. It is evident by comparison of the two tables that the ratio of the dead to those evacuated to the United States, and to those returned to duty, remains relatively unchanged. The inclusion of multiple wounds with those classified under single anatomic regions may lead to duplication and confusion. For this reason, multiple wounds have not been included in any tables except those devoted to the analysis of head wounds.

TABLE 68.—*Distribution of 505 casualties with head wounds (including multiple wounds), by category*

Category	Casualties	
	Number	Percent
Killed-in-action	165	32.7
Died of wounds	12	2.4
Total	177	35.1
Wounded, living:		
Evacuated to United States	62	12.3
Returned to duty from—		
First echelon [1]	196	38.8
Rear echelon [2]	70	13.8
Total	328	64.9
Grand total	505	100.0

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

Thoracic wounds accounted for 12.9 percent of all battle casualties. Of the dead, 66 were killed in action. Of the 21 who were wounded in action and died later, 15 died during or following operation. Perforating wounds of the thorax were present in all those who were killed or died later. Of 63 patients returned to duty in the first echelon, only 3 had wounds which penetrated the pleural cavity; all others had wounds of the chest wall only. In the group of 47 patients returned to duty from the rear echelon, 33 sustained chest wall wounds only. Among the remaining 14 with lesions involving the lung or pleura, 6 underwent lung operation. Of 34 patients who were evacuated to the United States, 24 had injuries of the lung; 19 of this latter group were treated by surgical operation and 5 by conservative measures. The remaining 10 patients had wounds of the chest wall which did not communicate with the pleural cavity.

A total of 114 patients sustained abdominal wounds. The abdomen was struck less frequently than any other anatomic region, and these wounded constituted the smallest number (6.4 percent) of all casualties. In 10 patients, wounds involving both the abdomen and thorax with perforation of the diaphragm were present. Twenty patients were killed in action, one of whom sustained a transection of the spinal cord. A relatively greater number (28, 24.6 percent) of patients were wounded in action and died later in this group than any other. Of these 28 patients, only 3 died without operation. In most instances, death resulted either from shock and hemorrhage or from peritonitis. The entire group of 19 patients returned to duty in the first echelon had wounds of the abdominal wall only. Of 23 patients returned to duty from the rear echelon, 13 had abdominal wall wounds; 1 had a combined thoracoabdominal wound; and the remainder had visceral lesions distributed as follows: Liver, 4; colon, 2; spleen, kidney, and bladder, 1 each. Fewer patients wounded in the abdomen (36.9 percent) were able to return to duty, than were those wounded in any other region. Of the 24 patients evacuated to the United States, 18 had injuries of the abdominal viscera, 5 had abdominal wall wounds, and 1 a transection of the cauda equina. The visceral lesions among these patients were distributed as follows: Small intestine, 6; small intestine and colon, 4; colon, 3; spleen and diaphragm, 2; stomach and liver, colon and diaphragm, and bladder, 1 each.

Wounds of the upper extremity alone constituted 17.9 percent of all battle casualties, yet wounds of this region carry a death risk of only 0.3 percent. No patients died who received treatment. The number of patients returned to duty in the first echelon is greater among those receiving upper extremity wounds than among those wounded in any other region. Of these 175 patients, 4 had fractures of the hand and 2, incomplete fractures of the arm. In the 68 patients returned to duty from the rear echelon, there were 12 fractures as follows: 6 of the bones of the hand and 2 each of the scapula, humerus, and forearm. In the 76 patients evacuated to the United States, there were 58 compound fractures and 5 amputations. The fractures were distributed as follows: Humerus, 23; bones of the forearm, 19; bones of the hand, 12; and scapula, 4. The percentage of patients evacuated to the United States was higher in upper extremity wounds than in wounds of any other anatomic region.

Wounds of the lower extremity were the most numerous of all battle wounds (22.7 percent) and accounted for next to the lowest mortality of any region (1.5 percent KIA). There were six casualties classed as killed in action, although with one exception all were alive when first seen. These soldiers either could not be reached or else died before adequate medical aid could be given. There were eight patients who were wounded in action and died later. Seven of these died in the first echelon and one in the second echelon. Of the seven deaths in the first echelon, two resulted from gas gangrene and five from shock and hemorrhage. Two deaths in the latter group might have been avoided by the use of a tourniquet. From the first echelon, 195 patients were

returned to duty. With the exception of one patient who had a chip fracture of the tibia, all of these patients had soft-tissue wounds only. From the rear echelon, 113 patients were returned to duty, 8 of whom had fractures of the bones of the leg and 4 of the bones of the foot. In 85 patients evacuated to the United States, there were 58 compound fractures distributed as follows: Bones of the leg, 31; femur, 18; and bones of the foot, 9. In addition, there were 10 amputations of the thigh or leg.

The risk of death in wounds of the extremities is low. In 727 casualties with wounds of the upper and lower extremities, there were 15 deaths (2.0 percent). On the other hand, wounds of the extremities constituted half of all patients evacuated to the United States. The majority of patients with wounds of the extremities, who were lost to the service by evacuation, had fractures as shown in table 69. Fractures among upper extremity wounds are more common (29.5 percent) than among the lower extremity lesions (18.3 percent). The greater relative volume of soft tissue to bone in the lower extremity may explain the lower incidence of fracture. On the other hand, the explanation may lie in the fact that the percentage of high-velocity missile

TABLE 69.—*Disposition of 319 casualties with wounds of upper extremities and 393 casualties with wounds of lower extremities*

Disposition	Total living wounded		Fractures		Nonfractures	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Upper extremity wound					
Returned to duty from—						
First echelon [2]	175	54.9	6	3.4	169	96.6
Rear echelon [3]	68	21.3	20	29.4	48	70.6
Evacuated to United States	76	23.8	68	89.5	8	10.5
Total	319	100.0	94	29.5	225	70.5
	Lower extremity wound					
Returned to duty from—						
First echelon [2]	195	49.6	1	0.5	194	99.5
Rear echelon [3]	113	28.8	13	11.5	100	88.5
Evacuated to United States	85	21.6	58	68.2	27	31.8
Total	393	100.0	72	18.3	321	81.7

[1] Percent for dichotomy, fractures versus nonfractures, under each disposition category and for total fractures versus nonfractures by upper and lower extremity wounds.
[2] Defined as the beachhead perimeter on Bougainville Island.
[3] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

wounds are slightly greater in the upper than in the lower extremity. Bullets produced 36.9 percent of all wounds of the upper extremity and 27.9 percent of the wounds of the lower extremity. Patients who returned to duty in the first and second echelons usually had fractures of small bones, chip and perforating fractures, and other fractures with minimal bone damage. It should be noted that 89.5 percent of the patients with wounds of the upper extremity and 68.2 percent of those with wounds of the lower extremity were evacuated to the United States because of fractures. The cause of fractures is discussed further in a later section devoted to the relative effect of weapons.

Wounds were classed as multiple only if two or more wounds of different regions could have caused death or disability. Such wounds caused 18.6 percent of all battle casualties. As in wounds of the head when death occurred, it was usually instantaneous. On the other hand, a relatively high percentage of patients with multiple wounds were returned to duty. In a group of 91 patients returned to duty from the first echelon, there were 203 soft-tissue wounds distributed as follows: Upper extremity, 73; lower extremity, 61; thoracic wall, 22; face and neck, 20; scalp, 14; abdominal wall, 8; and eye, 5. Present also were chip fractures of the clavicle, finger, and leg. From the rear echelon, 82 patients were returned to duty with 186 soft-tissue wounds distributed as follows: Upper extremity, 62; lower extremity, 61; thoracic wall, 24; face and neck, 17; scalp, 10; abdominal wall, 8; abdominal perforations, 2 (spleen and rectum); eye, 1; and lung perforation, 1. There were 8 chip fractures, 6 of the upper and 2 of the lower extremity, and also 2 perforating fractures of the pelvis; in addition, there were 2 finger amputations. There was a total of 151 soft-tissue wounds and fractures in 58 patients who were evacuated to the United States. The 38 fractures were distributed as follows: Upper extremity, 20; lower extremity, 16; and jaw, 2. The following soft-tissue wounds were present: Upper extremity, 36; lower extremity, 34; thoracic wall, 16; face and neck, 12; eye, 5; amputations, 5; scalp, 3; brain, 1; and abdominal wall, 1. Among these patients with multiple wounds, fractures were the chief cause for evacuation to the United States.

The anatomic distribution of wounds may vary according to the type of weapon causing the wound, the degree of exposure of different parts of the body, the protection afforded by various means, and the direction of fire. If the body were unprotected in an atmosphere of flying missiles of equal distribution, wounding should occur in direct proportion to the exposed surface area. However, such a theoretical condition never exists. On the contrary, missiles usually move in one direction at a given time. The projected area of the body if completely exposed, therefore, offers a better measure for the study of the probable hits. The mean projected body area[10] is obtained from projection in three positions, standing, kneeling, and lying. The hits with all weapons are compared with the mean projected body area (table 70). The head is the only region in which the percentage of wounds appreciably ex-

[10] Burns, B. D., and Zuckerman, S.: The Wounding Power of Small Bomb and Shell Fragments. R. C. No. 350 of the Research and Experiments Department of the Ministry of Home Security.

ceeded the percentage of the projected area for that region. The percentage of hits in the abdominal area is considerably less than the percentage of its projected area. The question may be raised why wounds of the head so far exceed the projected head area. Was this due to good marksmanship or exposure? Obviously, the head must be exposed for marksmanship to be effective. Since wounds caused by rifle bullets and mortar shell fragments were found in significant numbers and the circumstances were known with reasonable accuracy, they may be compared. The directed fire of the rifle and the undirected hits with mortar fragments were found to approximate closely the total hits by all weapons. This is evidence that exposure is one of the chief factors in accounting for the high incidence of head wounds. Nevertheless, the number of wounds caused by rifle fire does exceed the number caused by mortar fragments in the head, upper extremity, and thorax. This may be interpreted as evidence that marksmanship does play a small but important part in the high incidence of head wounds. This observation is further substantiated by the fact that the lower extremity presents the reverse of these findings.

TABLE 70.—*Mean projected body area and wound distribution (excluding multiple wounds)*

Anatomic location	Mean projected body area	Total hits for all weapons [1]		Total hits for rifle		Total hits for mortar	
		Number	Percent	Number	Percent	Number	Percent
	Percent						
Head	12.0	384	26.4	119	29.1	127	23.7
Thorax	16.0	231	15.9	66	16.2	79	14.7
Abdomen	11.0	114	7.8	30	7.3	39	7.3
Extremities:							
Upper	22.0	320	22.0	99	24.2	119	22.2
Lower	39.0	407	27.9	95	23.2	172	32.1
Total	100.0	1,456	100.0	409	100.0	536	100.0

[1] Includes all other weapons in addition to rifle and mortar which are shown specifically.

THE DIFFERENT WEAPONS CAUSING BATTLE CASUALTIES

It is obvious that the number of battle casualties produced by various weapons will depend upon the type of warfare, the number of weapons employed, and the training and tactics of the opposing forces. Thus, the measure of effectiveness of a given weapon must, of necessity, vary according to the circumstances under which it is used. The effectiveness of a weapon depends not only upon the total number of casualties it produces but also upon the ratio of the killed to wounded and upon the severity of the wound. In a certain local situation, the most effective weapon might be one which temporarily disabled the greatest number of the enemy and hence allowed the capture of a particular

objective or the winning of a single battle. If the effectiveness of a weapon is to be measured by this latter criterion, it would be necessary to set up an arbitrary definition of "temporary disability." In this event, a solution of the problem would be found in classifying the wounded on the basis of "ability to continue combat if life depended upon it."

The ratio of the killed to wounded is subject to various interpretations and must be clarified. As previously stated, the term "killed in action" in this study indicates those killed instantly and those who were mortally wounded and died within a relatively short time. Because of the proximity of medical installations on Bougainville, many mortally wounded patients lived to reach the hospital and were classified among those who were wounded in action and died later. Doubtless, under other less propitious circumstances, many of these casualties would have been classified with those who were killed in action. The term "dead" refers to the total number of those killed in action and those who were wounded-treated-died-later.

Since the severity of a wound is an abstract quality, open to individual interpretation and judgment and hence to consequent error, it was necessary to establish another criterion by which to judge the degree of disability sustained. The ultimate disposition of the patient seemed to offer a more reasonable basis for this estimation. All wounded, therefore, were separated into three groups depending upon whether the nature of the wound allowed the patient to be returned to duty from the first or from the rear echelon or whether it necessitated his evacuation to the United States. It is recognized that this is an arbitrary standard and open to the criticism that it is also an index of medical care; nevertheless, it is a factual and objective measure of the relative effect of weapons in the living wounded.

A fairly comprehensive description of the common types of Japanese weapons used on Bougainville has already been presented (pp. 289–292). From wound examination alone, it was never possible to distinguish the caliber of rifle or machinegun bullets nor the size of explosive shells. It was frequently impossible to judge with any accuracy whether the wound had been produced by a bullet or grenade shell or bomb fragment. Aerial bombing by the enemy did not occur during the Battle of the Perimeter. Miscellaneous weapons producing wounds were the bomb (U.S. aerial bombs), 13; pistol, 13; bangalore torpedo, 9; powder explosion, 5; bayonet, 2; bazooka, 1; and parachute flare, 1.

The Relative Lethal Effect of Weapons

The phrase "relative lethal effect" of a weapon refers to the percentage of deaths among the total number of casualties (dead and wounded) caused by that particular weapon. As previously stated, the ratio of the number of deaths to the number of casualties produced by any given weapon depends upon such variable factors as the type of action (offensive or defensive), number of weapons employed, terrain, exposure, and available protection. These factors

determine primarily the necessary degree of exposure of the soldier and consequently the number of hits, other factors being equal. The type and number of the particular weapon employed is then of prime importance in determining the relative lethal effect. For example, a small number of machineguns may produce few casualties but a "high lethal effect," [11] whereas a great many casualties may result from heavy mortar fire yet the lethal effect will remain relatively low.[12]

A comparison of the incidence of casualties caused by different weapons (table 71) shows that the mortar wounded more men (38.8 percent) than any other weapon. This was the weapon most feared by Allied troops. However, the relative lethal effect of the mortar is low (11.8 percent), rating next to the grenade which has the lowest (6.2 percent) relative lethal effect. There were 1,741 casualties caused by HE shells, grenades, landmines, and bullets and 47 casualties produced by miscellaneous weapons. High explosive shells, grenades, and mines caused wounds in 1,145 men (64.1 percent), but only 153 deaths (38.7 percent) occurred in this group. In contrast, bullets hit a total of 596 men (33.3 percent), but they accounted for 230 deaths (58.3 percent of total hit). The rifle was responsible for wounds in 445 casualties with a lethal effect of 32.1 percent. The machinegun, while causing fewer casualties (151), had the highest lethal effect of 57.6 percent. The very low lethal effect of the grenade (6.2 percent) is a characteristic probably peculiar to the Japanese hand grenade. Of the 34 landmine casualties, 33 were produced by U.S. mines. The 47 casualties (2.6 percent) listed under miscellaneous weapons were caused by pistols, bangalore torpedoes, bazookas, flares, powder explosions, and bayonet wounds.

Table 72 is a breakdown of the various causative agents according to the anatomic distribution (regional frequency) of wounds in the 1,788 casualties.

TABLE 71.—*Distribution of 1,788 battle casualties, by relative lethal effect of causative agent*

Causative agent	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Rifle	445	24.9	143	32.1	302	67.9
Machinegun	151	8.4	87	57.6	64	42.4
Artillery	194	10.9	44	22.7	150	77.3
Mortar	693	38.8	82	11.8	611	88.2
Grenade	224	12.5	14	6.2	210	98.3
Mines	34	1.9	13	38.2	21	61.8
Miscellaneous	47	2.6	12	25.5	35	74.5
Total	1,788	100.0	395	22.1	1,393	77.9

[1] Percent for dichotomy, dead versus living, by each causative agent and for total dead versus living.

[11] High mortality—low morbidity.—J. C. B.
[12] High morbidity—low mortality.—J. C. B.

There were 384 casualties (21.4 percent of the total number) due to wounds of the head alone. Moreover, wounds of the head (144) accounted for 37.5 percent of all dead. Excluding the 5 wounded by miscellaneous weapons, 208 head casualties (54.2 percent) were produced by high explosives (fragments) and 171 (44.5 percent) by bullets. However, high explosives accounted for

TABLE 72.—*Relative lethal effect of weapons, by anatomic location of wounds and for multiple wounds*

Causative agent	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Head wounds					
Rifle	119	31. 0	65	54. 6	54	45. 4
Machinegun	52	13. 5	40	76. 9	12	23. 1
Artillery	46	12. 0	15	32. 6	31	67. 4
Mortar	127	33. 1	20	15. 7	107	84. 3
Grenade	32	8. 3	1	3. 1	31	96. 9
Mine	3	. 8	3	100. 0		
Miscellaneous	5	1. 3			5	100. 0
Total	384	100. 0	144	37. 5	240	62. 5
	Thoracic wounds					
Rifle	66	28. 6	34	51. 5	32	48. 5
Machinegun	25	10. 8	18	72. 0	7	28. 0
Artillery	29	12. 5	16	55. 2	13	44. 8
Mortar	79	34. 2	14	17. 7	65	82. 3
Grenade	24	10. 4	3	12. 5	21	87. 5
Mine	3	1. 3	1	33. 3	2	66. 7
Miscellaneous	5	2. 2	1	20. 0	4	80. 0
Total	231	100. 0	87	37. 6	144	62. 3
	Abdominal wounds					
Rifle	30	26. 3	14	46. 7	16	53. 3
Machinegun	17	14. 9	13	76. 5	4	23. 5
Artillery	8	7. 0	3	37. 5	5	62. 5
Mortar	39	34. 2	12	30. 8	27	69. 2
Grenade	14	12. 3	3	21. 4	11	78. 6
Mine						
Miscellaneous	6	5. 3	3	50. 0	3	50. 0
Total	114	100. 0	48	42. 1	66	57. 9

See footnote at end of table.

TABLE 72.—*Relative lethal effect of weapons, by anatomic location of wounds and for multiple wounds*—Continued

Causative agent	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Upper extremity wounds					
Rifle	99	30.9			99	100.0
Machinegun	21	6.6			21	100.0
Artillery	36	11.3			36	100.0
Mortar	119	37.2	1	.8	118	99.2
Grenade	33	10.3			33	100.0
Mine	1	.3			1	100.0
Miscellaneous	11	3.4			11	100.0
Total	320	100.0	1	.3	319	99.7
	Lower extremity wounds					
Rifle	95	23.3	6	6.3	89	93.7
Machinegun	17	4.2	1	5.9	16	94.1
Artillery	52	12.8	1	1.9	51	98.1
Mortar	172	42.3	5	2.9	167	97.1
Grenade	59	14.5	1	1.7	58	98.3
Mine	5	1.2			5	100.0
Miscellaneous	7	1.7			7	100.0
Total	407	100.0	14	3.4	393	96.6
	Multiple wounds					
Rifle	36	10.9	24	66.7	12	33.3
Machinegun	19	5.7	15	78.9	4	21.1
Artillery	23	6.9	9	39.1	14	60.9
Mortar	157	47.3	30	19.1	127	80.9
Grenade	62	18.7	6	9.7	56	90.3
Mine	22	6.6	9	40.9	13	59.1
Miscellaneous	13	3.9	8	61.5	5	38.5
Total	332	100.0	101	30.4	231	69.6

[1] Percent for dichotomy, dead versus living, by each causative agent and for total dead versus living by anatomic location of wounds and for multiple wounds.

only 27.1 percent of the dead, whereas bullets were responsible for 72.9 percent. Thus, while high explosives caused more casualties, the lethal effect produced was relatively low. This may be explained by the average lower velocity of shell fragments and the relative greater protection afforded against them by

the helmet and skull. This is further substantiated by the fact that in 92.3 percent of the deaths due to head wounds, the skull had been penetrated.

Wounds of the thorax accounted for 12.9 percent of all casualties and for 22.0 percent of all deaths. Excluding 5 wounded by miscellaneous weapons, high explosives (fragments) produced 135 casualties (60 percent) and bullets 91 (40 percent). However, again contrasting relative lethal effects, bullets accounted for 59.7 percent of the deaths and high explosives for 40.3 percent. In thoracic wounds, the contrast between the lethal effect of wounds due to high explosives and bullets is not so pronounced as in wounds of the head. Possibly, this is due to the fact that the thoracic cage offers less protection to the vital organs than does the skull and helmet. This hypothesis seems to be substantiated further by the fact that while the lethal effect of both mortar and artillery fragments is increased in the thorax, the lethal effect of the grenade is increased fourfold. Bullet wounds were limited to the chest wall in only 18 instances, while high explosives caused 85 wounds which did not penetrate the thoracic cavity. The relatively lower velocity of some of the HE shell fragments would appear to account for its frequent failure to penetrate the thorax.

Casualties occasioned by wounds of the abdomen had the lowest incidence and accounted for only 6.4 percent of the total wounded and 12.1 percent of of the dead. Whereas, high explosives (fragments) caused 56.2 percent of the casualties due to abdominal wounds, bullets accounted for 62.5 percent of the deaths from these wounds. This ratio may represent a distorted picture when compared to findings in other theaters, since it is based on such a small number (8) of wounds of the abdomen caused by artillery shells. However, the mortar and the grenade show almost twice the relative lethal effect in wounds of the abdomen as they do in wounds of the thorax. This is further evidence that the bony structures of the body wall may offer considerable effective protection against these low-velocity fragments. High explosive fragments caused 30 of the 53 wounds perforating the abdominal cavity, which would appear to indicate a relatively high index of penetration. Nevertheless, the relative protection afforded by the abdominal wall to low-velocity fragments should also be mentioned. Of 38 wounds limited to the abdominal wall, 30 were caused by HE fragments.

Wounds of the upper extremity accounted for 17.9 percent of all casualties and for only 0.3 percent of the dead. High explosive fragments caused 59.1 percent of these wounds. More than half of all wounds caused by high explosives were due to mortar shells. The relative effectiveness of bullets and HE fragments may be judged from the severity of the wound as indicated by the disposition of the patients shown in table 73.

The one death among the upper extremity casualties was caused by a mortar shell. Since the lethal effect of wounds of the upper extremity was negligible, it deserves no discussion.

Wounds of the lower extremity accounted for the highest number of casualties (22.7 percent). However, lower extremity wounds were responsible for only 3.5 percent of all deaths. High explosives caused 70.8 percent of lower

extremity casualties; of these, mortar shells alone were responsible for more than half. Bullets, however, caused 7 of the 14 deaths. The severity of wounds caused by bullets and high explosives may be judged by the disposition of casualties as shown in table 74.

TABLE 73.—*Disposition of 123 and 196 casualties with upper extremity wounds, by relative effectiveness of bullets and HE fragments, respectively*

Disposition	Casualties wounded by—			
	Bullets		HE fragments	
	Number	Percent	Number	Percent
Returned to duty from—				
First echelon [1]	44	35. 7	131	66. 8
Rear echelon [2]	33	26. 8	35	17. 8
Evacuated to United States	46	37. 5	30	15. 4
Total	123	100. 0	196	100. 0

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

TABLE 74.—*Disposition of 110 and 283 casualties with lower extremity wounds, by relative effectiveness of bullets and HE fragments, respectively*

Disposition	Casualties wounded by—			
	Bullets		HE fragments	
	Number	Percent	Number	Percent
Returned to duty from—				
First echelon [1]	44	40. 0	151	53. 4
Rear echelon [2]	30	27. 3	83	29. 3
Evacuated to United States	36	32. 7	49	17. 3
Total	110	100. 0	283	100. 0

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

Wounds of the extremities constituted the largest group of battle casualties in this survey and accounted for 40.6 percent of all wounds. These wounds, however, accounted for the smallest number of dead (3.8 percent). Since relatively few deaths resulted from wounds of this region, the effectiveness of weapons on the extremities must be judged by the duration of the soldiers' incapacity and by the number of casualties lost to the service by evacuation to the rear echelon and to the United States. In view of the fact that fractures were the chief cause of evacuation to the United States, the

relative effect of weapons on the extremities was also judged by the number of fractures they caused. The rifle caused the greatest number of fractures in both the upper and lower extremities (table 75). In the upper extremity, the rifle led not only in the number but also in the percentage chance of fracture. In general, the chance of fracture appeared to parallel the velocity of the missile. Bullets caused only 37.5 percent of upper extremity and 26.3 percent of lower extremity wounds, whereas these missiles caused 66 percent of upper extremity and 60 percent of lower extremity fractures.

TABLE 75.—*Relative effect of weapons causing wounds of upper and lower extremities, among the living wounded*

Causative agent	Total wounds		Fracture		Nonfracture	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Upper extremity					
Rifle	99	31. 0	55	55. 5	44	44. 5
Machinegun	21	6. 6	7	33. 3	14	66. 7
Artillery	36	11. 3	6	16. 7	30	83. 3
Mortar	118	37. 0	18	15. 3	100	84. 7
Grenade	33	10. 3	4	12. 2	29	87. 8
Miscellaneous	12	3. 8	4	33. 3	8	66. 7
Total	319	100. 0	94	29. 5	225	70. 5
	Lower extremity					
Rifle	89	22. 6	28	31. 5	61	68. 5
Machinegun	16	4. 1	9	56. 2	7	43. 8
Artillery	51	13. 0	9	17. 6	42	82. 4
Mortar	167	42. 5	15	8. 9	152	91. 1
Grenade	58	14. 7	4	6. 9	54	93. 1
Mine	5	1. 3	5	100. 0		
Miscellaneous	7	1. 8	2	28. 6	5	71. 4
Total	393	100. 0	72	18. 3	321	81. 7

[1] Percent for dichotomy, fracture versus nonfracture, by each causative agent and for total fracture versus nonfracture, by upper and lower extremity wounds.

Casualties due to multiple wounds rated third in incidence and constituted 18.6 percent of the total number. High explosives caused 79.5 percent of these wounds and 53.5 percent of the resultant deaths; however, the machinegun and rifle showed the highest relative lethal effect. The severity of multiple wounds caused by bullets and high explosives as judged by the disposition of casualties is shown in table 76.

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TABLE 76.—*Disposition of 16 and 215 casualties with multiple wounds, by relative effectiveness of bullets and HE fragments, respectively*

Disposition	Casualties wounded by—			
	Bullets		HE fragments	
	Number	*Percent*	*Number*	*Percent*
Returned to duty from—				
First echelon[1]	2	12. 5	89	41. 4
Rear echelon[2]	8	50. 8	74	34. 4
Evacuated to United States	6	37. 5	52	24. 2
Total	16	100. 0	215	100. 0

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

The Dead

Table 77 shows the distribution of the dead according to the causative weapon. There were 395 dead of whom 230 or 58.2 percent were killed by bullets. Of these 395 dead, 75 (19 percent) were wounded in action, treated, and died later. Of these 75 patients, 50 died within 24 hours; of these 50, 40 were classed as mortally wounded. Had medical facilities been further removed from the frontline or had transportation problems been more difficult, a large number of those who were wounded and died later would, no doubt, have been classed as KIA. Bullet wounds tended to produce more immediate fatalities than did wounds produced by mortar and artillery shells. Among those who were wounded and died later, wounds were produced by the mortar in 28.0 percent, by artillery in 27.3 percent, and by the rifle in 14.7 percent.

TABLE 77.—*Distribution of 395 fatal casualties, by relative effect of causative agent*

Causative agent	Total dead		Killed in action		Died of wounds	
	Number	Percent	Number	Percent[1]	Number	Percent[1]
Rifle	143	36. 2	122	85. 3	21	14. 7
Machinegun	87	22. 0	72	82. 8	15	17. 2
Artillery	44	11. 1	32	72. 7	12	27. 3
Mortar	82	20. 8	59	72. 0	23	28. 0
Grenade	14	3. 6	11	78. 6	3	21. 4
Mine	13	3. 3	12	92. 3	1	7. 7
Miscellaneous	12	3. 0	12	100. 0	--------	--------
Total	395	100. 0	320	81. 0	75	19. 0

[1] Percent for dichotomy, killed in action versus died of wounds, by causative agent and for total killed in action versus died of wounds.

Effectiveness of Weapons

To measure the effectiveness of a weapon by the number of casualties it produces may lead to erroneous conclusions. To reiterate, the number of casualties depends on such factors as the necessary exposure of the soldier, the concentration of troops, the number of weapons employed, and the effect of the missile. It is seldom that all these varying conditions of battle can be duplicated. On the other hand, the percentage chance of death and the length of disability when hit by a given weapon should remain relatively constant and, therefore, should offer a fairly accurate index of the effectiveness of various missiles.

The percentage chance of death when hit by various weapons is shown in table 78. Casualties receiving two or more wounds, either one of which might have produced death, are not included in this table, but are discussed under "Multiple Wounds." Nevertheless, many of these casualties did have more than one wound. The order of these weapons suggests that the chance of being killed is a function of the velocity of the missile. The risk of death when hit by a machinegun in the head, chest, or abdomen is approximately equal. The contrast in death risk between the machinegun (54.5 percent) and the rifle (29.1 percent) is not entirely due to multiplicity of hits, since multiple hits were found not infrequently with rifle fire. On the average, machinegun fire originated at a closer range than rifle fire, 61 percent of the hits being from less than 50 yards. The chance of death when hit by a grenade (4.9 percent) is approximately half that when hit by the mortar (9.7 percent). The risk of death when hit in the abdomen by mortar or grenade is relatively greater than when hit in the head or thorax. This suggests that the helmet and skull (fig. 179) as well as the ribs may offer considerable protection against many of these relatively low-velocity fragments.

The relative effect of weapons may be judged by the percentage chance of a light wound or of a severe wound (tables 79 and 80). These tables are based on living wounded only. A light wound was defined as one which allowed return to duty in the first echelon and a severe wound as one which necessitated evacuation to the United States. There appears to be considerable difference in the severity of a wound according to the anatomic region hit, as well as to the weapon causing it. In general, high explosives (fragments) tend toward light wounds while small arms (bullets) tend toward more severe wounds.

The relative effectiveness of weapons may also be evaluated by a consideration of the total dead plus the total evacuated to the United States. Together, these may be considered as "lost to the service" (table 81), although some who were returned to the United States may serve in future campaigns. It should be noted by this criterion that wounds of the extremities and abdomen assume a far greater relative importance than when death alone is utilized as an index of weapon effectiveness.

TABLE 78.—*Relative effect of weapons: Probability of hits resulting in death, by anatomic location of wounds (excluding multiple wounds)*

Weapon [1]	Total areas			Head			Thorax			Abdomen			Extremities		
	Hits	Deaths	Hits resulting in death	Hits	Deaths	Hits resulting in death	Hits	Deaths	Hits resulting in death	Hits	Deaths	Hits resulting in death	Hits	Deaths	Hits resulting in death
	Number	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Percent*
Rifle	409	119	29. 1	119	65	54. 6	66	34	51. 5	30	14	46. 7	194	6	3. 1
Machinegun	132	72	54. 5	52	40	76. 9	25	18	72. 0	17	13	76. 5	38	1	2. 6
Artillery	171	35	20. 5	46	15	32. 6	29	16	55. 2	8	3	37. 5	88	1	1. 1
Mortar	536	52	9. 7	127	20	15. 7	79	14	17. 7	39	12	30. 8	291	6	2. 1
Grenade	162	8	4. 9	32	1	3. 1	24	3	12. 5	14	3	21. 4	92	1	1. 1

[1] Excluding mines and miscellaneous agents.

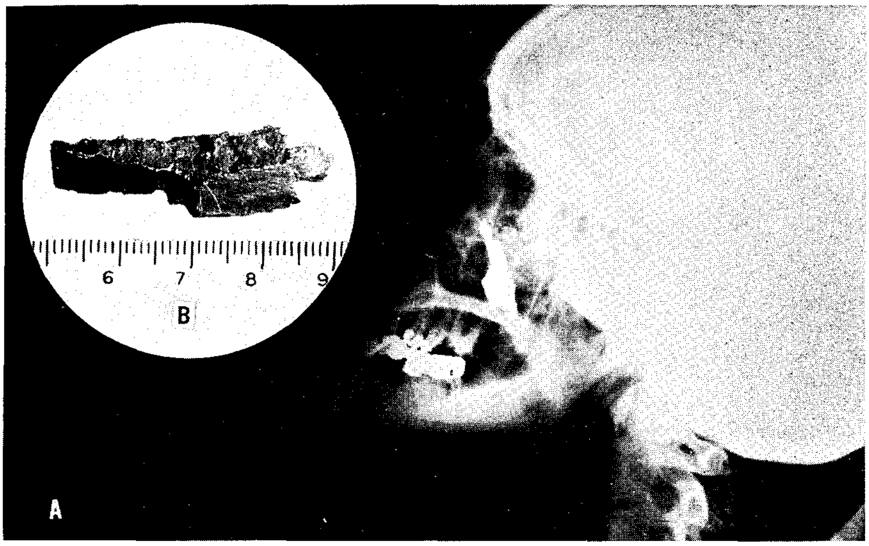

FIGURE 179.—Roentgenogram of skull showing artillery shell fragment lodged in sinus cavity. A soldier, standing in the company area, was hit by a Japanese 75 mm. artillery shell which exploded at a distance of 100 yards. A fragment of the shell penetrated the outer wall of the maxillary sinus and lodged in the sinus cavity. This is a good example of the relative protection afforded by bony structures to low-velocity fragments, even of large size. A. X-ray of skull. B. Recovered fragment.

Table 82 shows the number of patients returned to duty from the first echelon (Bougainville). Table 83 shows the total number of casualties dead and evacuated to the rear echelon and to the United States. These were lost to the Bougainville campaign. Note that the percentage effectiveness of each weapon suggests a possible correlation with the average velocity of hits.

Conditions of battle may be such that the effectiveness of a weapon can best be measured by whether the wounded soldier was able to continue fighting. Hence, the number of casualties per se is not a sufficient criterion since many of the wounded may continue to fight and hold off the enemy, at least temporarily. It is, therefore, desirable to know the number who are put out of action immediately and the number who could continue combat for a period of hours, if life depended on it. A questionnaire to determine whether an individual did or did not continue combat was found to be misleading, since conditions of battle were frequently such as to permit the soldier to seek immediate treatment. This he usually did when possible, since he had been so instructed by Medical Corps personnel. However, there were numerous instances of soldiers who were severely wounded and yet who continued to hold their position in the line until relieved. (For example: Two soldiers were holding a pillbox at night under Japanese attack. Eventually, each had a hand blown off, but with two hands between them, they cared for their wounds, manned their guns, and held off the attack until relieved at daybreak.)

TABLE 79.—*Relative effect of weapons: Probability of causing light wounds* [1]

Weapon	Total			Head			Thorax			Abdomen			Extremities		
	Survived	Returned to duty	Percent	Survived	Returned to duty	Percent	Survived	Returned to duty	Percent	Survived	Returned to duty	Percent	Survived	Returned to duty	Percent
Rifle	290	110	37. 9	54	32	59. 3	32	7	21. 9	16	3	18. 8	188	68	36. 2
Machinegun	60	22	36. 7	12	4	33. 3	7	3	42. 9	4	0	0	37	15	40. 5
Artillery	136	80	58. 8	31	25	80. 6	13	3	23. 1	5	3	60. 0	87	49	56. 3
Mortar	484	272	56. 2	107	70	65. 4	65	32	49. 2	27	8	29. 6	285	162	56. 8
Grenade	154	104	67. 5	31	21	67. 7	21	16	76. 2	11	3	27. 3	91	64	70. 3

[1] Based on percent of living wounded (survived less multiple wounded) returned to duty from first echelon (defined as the beachhead perimeter on Bougainville Island).

TABLE 80.—*Relative effect of weapons: Probability of causing serious nonfatal wounds* [1]

Causative agent	Total			Head			Thorax			Abdomen			Extremities		
	Survived	Evacuated to United States	Percent	Survived	Evacuated to United States	Percent	Survived	Evacuated to United States	Percent	Survived	Evacuated to United States	Percent	Survived	Evacuated to United States	Percent
Rifle	290	93	32. 1	54	10	18. 5	32	13	40. 6	16	4	25. 0	188	66	35. 1
Machinegun	60	28	46. 7	12	4	33. 3	7	3	42. 9	4	4	100. 0	37	17	45. 9
Artillery	136	23	16. 9	31	3	9. 7	13	2	15. 4	5	2	40. 0	87	16	18. 4
Mortar	484	83	17. 1	107	16	15. 0	65	11	16. 9	27	9	33. 3	285	47	16. 5
Grenade	154	26	16. 9	31	8	25. 8	21	3	14. 3	11	4	36. 4	91	11	12. 1

[1] Based on percent of living wounded (survived less multiple wounded) evacuated to the United States.

TABLE 81.—*Relative effect of weapons: Lost to service in the theater* [1]

Causative agent	Total			Head			Thorax			Abdomen			Extremities		
	Hit	Dead plus evacuated to United States	Percent	Hit	Dead plus evacuated to United States	Percent	Hit	Dead plus evacuated to United States	Percent	Hit	Dead plus evacuated to United States	Percent	Hit	Dead plus evacuated to United States	Percent
Rifle	409	212	51. 8	119	75	63. 0	66	47	71. 2	30	18	60. 0	194	72	37. 1
Machinegun	132	100	75. 8	52	44	84. 6	25	21	84. 0	17	17	100. 0	38	18	47. 4
Artillery	171	58	33. 9	46	18	39. 1	29	18	62. 1	8	5	62. 5	88	17	19. 3
Mortar	536	135	25. 2	127	36	28. 3	79	25	31. 6	39	21	53. 8	291	53	18. 2
Grenade	162	34	21. 0	32	9	28. 1	24	6	25. 0	14	7	50. 0	92	12	13. 0

[1] Percent of hits (dead plus survived, excluding multiple wounded) resulting in death or evacuation to the United States.

TABLE 82.—*Relative effect of weapons: Casualties returned to duty from first echelon* [1]

Weapon	Total casualties	Casualties returned to duty	
		Number	Percent of total
	Number		
Rifle	445	112	25. 2
Machinegun	151	22	14. 6
Artillery	194	84	43. 3
Mortar	693	325	46. 9
Grenade	224	133	59. 4

[1] Defined as the beachhead perimeter on Bougainville Island.

TABLE 83.—*Relative effect of weapons: Casualties lost to Bougainville campaign (dead or evacuated to rear echelon* [1] *or to United States)*

Weapon	Total casualties	Casualties lost to Bougainville campaign	
		Number	Percent of total
	Number		
Rifle	445	333	74. 8
Machinegun	151	129	85. 4
Artillery	194	110	56. 7
Mortar	693	368	53. 1
Grenade	224	91	40. 6

[1] To hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

An arbitrary criterion based on the seriousness of the wound seemed justified in order to determine whether a soldier will be able to continue in battle for a number of hours, if his life were at stake. For this purpose, an arbitrary schedule was derived, and the following wounded were classed as "Lost to Combat":

1. Wounds of the head and central nervous system producing unconsciousness or paralysis.
2. Wounds of intrathoracic structures producing hemorrhage and shock.
3. Wounds of intraperitoneal structures producing hemorrhage and shock.
4. Wounds of the extremities producing fractures of long bones, severance of major blood vessels, or major traumatic amputations.
5. Extensive wounds of soft tissue producing shock.

The wounded were classified according to the criteria listed and added to the dead to determine the total lost to combat (table 84). This table again suggests that the percentage effectiveness of the weapon is a function of the average velocity of the missiles.

Callender and others have shown that the wounding power of a missile is in proportion to the cube of the velocity, the mass and other factors being equal. In this report, the percentage effectiveness of weapons as judged by

the chance of death, and the severity of the wound, appears to be in accord with the observation that the wounding power of a missile is chiefly a function of velocity. When hits occur, the weapons in order of effectiveness are (1) machinegun, (2) rifle, (3) artillery, (4) mortar, and (5) grenade.

TABLE 84.—*Relative effect of weapons: Casualties lost to combat*

Weapon	Total casualties	Casualties lost to combat	
		Number	Percent
	Number		
Rifle	445	233	52. 4
Machinegun	151	114	75. 5
Artillery	194	59	30. 4
Mortar	693	170	24. 5
Grenade	224	42	18. 8

The Relative Effect of Weapons on the Disposition of Patients

An evaluation of the effectiveness of each weapon may be obtained by considering both the number killed and the severity of the wound as determined by the disposition of the patient.

There were 700 casualties returned to duty from the first echelon (defined as the beachhead perimeter on Bougainville Island). These patients spent an average of 12.7 days in the hospital (table 85). However, if the requirement had existed, the majority of these men would have been available for emergency combat duty in a shorter time. Nevertheless, the problem of the lightly wounded, treated in the first echelon, is of considerable importance, both because of days lost to the service and because these casualties occupy beds which might be needed for the more seriously wounded. Wounds caused by HE shell fragments constituted the major problem in the first echelon. Wounds of the extremities and multiple wounds comprised a majority of these lesions (table 86).

The rear echelon included hospitals on Guadalcanal, Espíritu Santo, and New Caledonia; the evacuation distances ranged from 400 to 1,500 miles from Bougainville. Consequently, patients evacuated to hospitals in the rear were lost to the service insofar as the Battle of the Perimeter was concerned. Subsequently, some of these patients were returned to duty from the rear echelon and performed service in combat units, hence were not lost to the South Pacific theater. The severity of the wounds in these casualties usually justified their removal to a rear echelon for convalescence. Only a very few were evacuated because of the need for additional vacant hospital beds on Bougainville. Hence, transfer to the rear echelon may be taken as a fair measure of the severity of a soldier's wound from the standpoint of his ability to undergo combat. The wounded were usually returned to duty from the

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TABLE 85.—*Days lost by 700 casualties returned to duty from first echelon [1] hospitals, by causative agent*

Causative agent	Casualties		Average number of days in hospital
	Number	Percent	
Rifle	112	16. 0	14. 2
Machinegun	22	3. 1	16. 6
Artillery	84	12. 0	12. 0
Mortar	325	46. 5	12. 0
Grenade	133	19. 0	12. 2
Mines and miscellaneous	24	3. 4	18. 0
Total	700	100. 0	12. 7

[1] Defined as the beachhead perimeter on Bougainville Island.

TABLE 86.—*Days lost by 700 casualties returned to duty from first echelon [1] hospitals, by anatomic location*

Anatomic locatfon	Casualties		Average number of days in hospital
	Number	Percent	
Head	157	22. 4	9. 0
Thorax	63	9. 0	11. 2
Abdomen	19	2. 7	18. 4
Extremities:			
Upper	175	25. 0	11. 7
Lower	195	27. 9	14. 9
Multiple	91	13. 0	15. 8
Total	700	100. 0	12. 7

[1] Defined as the beachhead perimeter on Bougainville Island.

rear echelon or were evacuated to the United States within 120 days. However, the average elapsed time before return to duty was considerably less than this.

Though many patients evacuated to the United States were returned to duty eventually, they must be considered as lost to the service for a long period.

Table 87 presents the anatomic distribution of the hits by the various causative agents, and table 88 lists the general disposition of the nonfatal casualties.

In number of wounds produced, the rifle was exceeded only by the mortar and was responsible for 24.9 percent of all battle casualties. However, the rifle ranked first as a lethal agent, accounting for 36.2 percent of all dead. Moreover, it was second in percentage relative lethal effect (32.1 percent), being exceeded only by the machinegun (57.6 percent). The rifle produced

wounding in 53.7 percent of all casualties lost to the service by death and evacuation to the United States. The rifle caused more head wounds than any other weapon and was second only to the machinegun in relative lethal effect in head wounds. It ranked third in relative lethal effect in thoracic wounds,

TABLE 87.—*Anatomic distribution (regional frequency) of wounds, by causative agents*

Anatomic location	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Rifle					
Head	119	26. 7	65	54. 6	54	45. 4
Thorax	66	14. 8	34	51. 5	32	48. 5
Abdomen	30	6. 7	14	46. 7	16	53. 3
Extremities:						
Upper	99	22. 3			99	100. 0
Lower	95	21. 4	6	6. 3	89	93. 7
ultiple	36	8. 1	24	66. 7	12	33. 3
Total	445	100. 0	143	32. 1	302	67. 9
	Machinegun					
Head	52	34. 4	40	76. 9	12	23. 1
Thorax	25	16. 5	18	72. 0	7	28. 0
Abdomen	17	11. 3	13	76. 5	4	23. 5
Extremities:						
Upper	21	13. 9			21	100. 0
Lower	17	11. 3	1	5. 9	16	94. 1
Multiple	19	12. 6	15	78. 9	4	21. 1
Total	151	100. 0	87	57. 6	64	42. 4
	Mortar					
Head	127	18. 3	20	15. 7	107	84. 3
Thorax	79	11. 4	14	17. 7	65	82. 3
Abdomen	39	5. 6	12	30. 8	27	69. 2
Extremities:						
Upper	119	17. 2	1	. 8	118	99. 2
Lower	172	24. 8	5	2. 9	167	97. 1
Multiple	157	22. 7	30	19. 1	127	80. 9
Total	693	100. 0	82	11. 8	611	88. 2

See footnote at end of table.

TABLE 87.—*Anatomic distribution (regional frequency) of wounds, by causative agents*—Con.

Anatomic location	Total casualties		Dead		Living	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
	Artillery					
Head	46	23.7	15	32.6	31	67.4
Thorax	29	14.9	16	55.2	13	44.8
Abdomen	8	4.1	3	37.5	5	62.5
Extremities:						
Upper	36	18.6			36	100.0
Lower	52	26.8	1	1.9	51	98.1
Multiple	23	11.9	9	39.1	14	60.9
Total	194	100.0	44	22.7	150	77.3
	Grenade					
Head	32	14.3	1	3.1	31	96.9
Thorax	24	10.7	3	12.5	21	87.5
Abdomen	14	6.3	3	21.4	11	78.6
Extremities:						
Upper	33	14.7			33	100.0
Lower	59	26.3	1	1.7	58	98.3
Multiple	62	27.7	6	9.7	56	90.3
Total	224	100.0	14	6.3	210	93.7

[1] Percent for dichotomy, dead versus survived, by each anatomic location and for total dead versus survived by each causative agent.

being exceeded by the machinegun and artillery shell, and second in abdominal wounds. While the rifle was second to the mortar in causing wounds of both the upper and lower extremities, it produced more fractures than any other weapon (fig. 180).

The machinegun caused fewer casualties than any other weapon, 8.4 percent. However, its percentage relative lethal effect was the highest of all weapons, 57.6 percent. It was not possible to separate the casualties produced by the 6.5 mm. weapon from those produced by the 7.7 mm. machinegun. The percentage lost to the service by death and evacuation to the United States was also the highest of any weapon, 78.1 percent. Measured by the number of patients lost to the service, machinegun wounds were the most severe among those produced by any weapon. This high degree of effectiveness of the machinegun bullet may be explained partially by close range fire in this campaign and also by the multiplicity of wounds. The percentage relative

FIGURE 180.—Roentgenogram of compound comminuted fracture of the humerus caused by a Japanese .25 caliber rifle bullet fired from a distance of 75 yards. This is a typical example of the explosive effect of the .25 caliber rifle bullet when it strikes bone or a solid organ. Many of these bullets caused similar damage to the arm and then passed through the chest.

TABLE 88.—*Disposition of 1,337 nonfatal casualties, by causative agent*

Causative agent	Total survived		Returned to duty						Evacuated to United States	
			Total		From first echelon [1]		From rear echelon [2]			
	Number	Percent [3]	Number	Percent [3]	Number	Percent [4]	Number	Percent [4]	Number	Percent [3]
Rifle	302	67. 9	206	46. 3	112	54. 4	94	45. 6	96	21. 6
Machinegun	64	42. 4	33	21. 9	22	66. 7	11	33. 3	31	20. 5
Mortar	611	88. 2	495	71. 5	325	65. 7	170	34. 3	116	88. 2
Artillery	150	77. 3	123	63. 4	84	68. 3	39	31. 7	27	13. 9
Grenade	210	93. 7	173	77. 2	133	76. 9	30	23. 1	37	16. 5
Total	1, 337	78. 4	1, 030	60. 4	676	65. 6	354	34. 4	307	18. 0

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.
[3] Percent of total casualties inflicted by causative agent.
[4] Percent for dichotomy, first echelon, versus rear echelon of those returned to duty (= 100 percent).

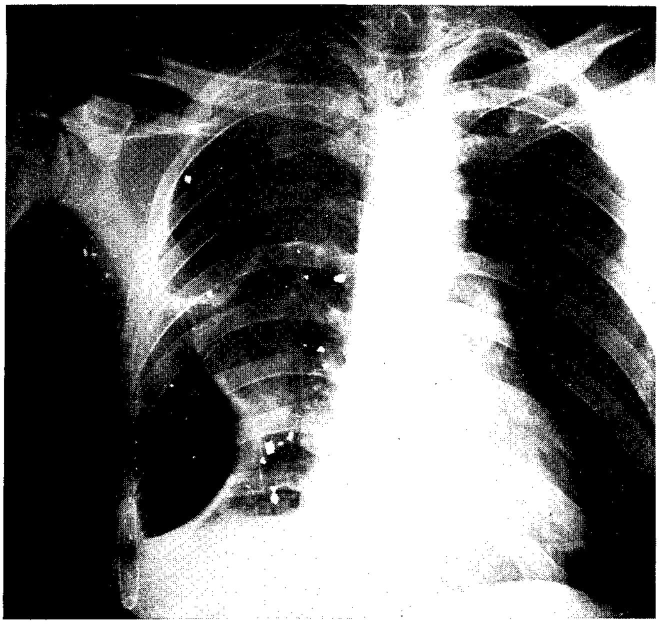

FIGURE 181.—Roentgenogram of thoracic cavity of soldier who was prone on the ground when a mortar shell of unknown size exploded 1-yard distant. This soldier was also wounded in the arm, thigh, and both ankles. An open operation was performed, and the numerous lacerations in the lung, caused by the small fragments, were sutured and the intercostal vessels ligated. The soldier made a good recovery.

lethal effect was uniformly high for all regions of the body with the exception of the extremities.

The mortar caused more wounds than any other weapon and accounted for 38.8 percent of all battle casualties. However, its relative lethal effect was only 11.8 percent (fig. 181). The only weapon having a lower lethal effect was the grenade. Furthermore, 71.5 percent of the living wounded were returned to duty, a higher percentage than for any other weapon except the grenade. The dead and evacuated to the United States (lost to the service) totaled 28.5 percent. The highest relative lethal effect (30.8 percent) was observed in wounds of the abdomen, whereas the greatest number of deaths occurred in multiple regional involvement.

The use of artillery by the enemy in this campaign was relatively limited. Wounds caused by artillery shells, however, accounted for 10.9 percent of the casualties and were fourth in frequency. Artillery ranked fourth in cause of death (11.1 percent) and fifth in percentage lethal effect, 22.7 percent. Among casualties evacuated to the United States, artillery produced the lowest number of wounds, 13.9 percent. However, the percentage of those lost to the service by death and evacuation to the United States was 36.6 percent. While wounds

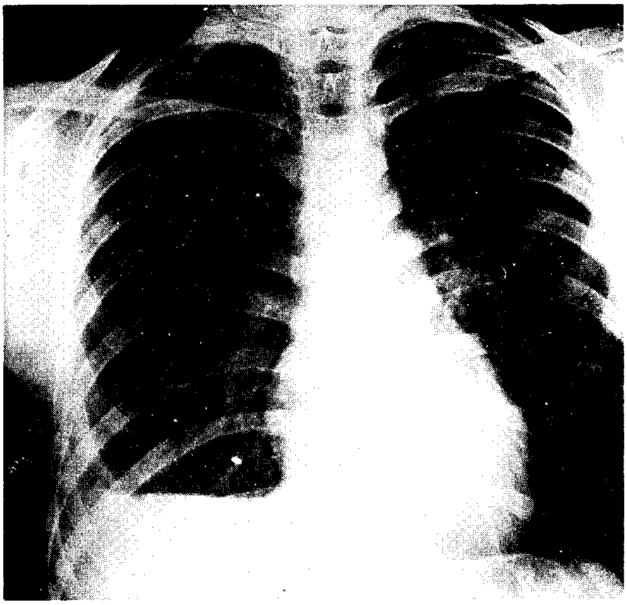

FIGURE 182.—Roentgenogram of thoracic cavity of soldier who was prone in a foxhole when a Japanese hand grenade exploded at a distance of not more than 1 foot from the chest wall. This X-ray shows the characteristic small fragments of the hand grenade. Most of the fragments were stopped by the chest wall, but some of them penetrated the pleura. The fragmentation of the Japanese hand grenade is irregular but usually very small.

of the extremities were frequent, only one death occurred. This death was produced by a lower extremity wound. Lethal wounds in order of frequency by regions were the thorax, head, multiple, abdomen, and lower extremity.

The grenade ranked third in wound production and accounted for 12.5 percent of all battle casualties (table 71). However, its relative lethal effect was the lowest of all weapons, 6.2 percent. Furthermore, the majority of the wounds were of a minor nature (fig. 182). The grenade was first among all weapons as gaged by the percentage of wounded returned to duty, 77.2 percent, and three-fourths of these patients were returned to duty from the first echelon. The grenade was responsible for the lowest number of casualties (22.8 percent) among those who were lost to the service by death and evacuation to the United States. Of all wounds produced by the grenade, 68.7 percent were classified as extremity wounds and multiple wounds.

Weapon Evaluation by Multiplicity of Wounds

The question has been frequently asked: Do missiles causing multiple wounds result in more serious casualties because of the number of wounds per se? The data available do not answer this question satisfactorily. Multiple

wounds were analyzed according to the number of different anatomic regions involved rather than by the total number of wounds. Thus, a patient with 10 wounds of the leg and 5 of the hand was classified under multiple wounds in two anatomic regions; that is, as an upper and a lower extremity casualty without regard to the number of lesions present.

Table 89 relates the casualties with multiple wounds to the number of anatomic regions involved and the severity of the wounds. The disposition of the patient was used to determine the severity of the wounds. The number of the multiple wounded casualties discharged in each echelon is tabulated by weapon. The corresponding number of anatomic regions hit is also recorded by weapon. Thus, there were 53 patients, with mortar wounds in 117 different anatomic regions, returned to duty in the first echelon. Therefore, among the patients returned to duty in this echelon, there were mortar wounds in 2.21 of the various anatomic regions per patient (table 90). The ratio of anatomic regions wounded per patient is slightly higher for each weapon among the casualties evacuated to the United States. However, the difference is so slight as to suggest that multiplicity of wounds alone is not a factor of great importance. The relatively low mortality of 3.3 percent for all patients with multiple wounds seen alive suggests that the multiple wounds per se add little to the risk. It is likely that the actual severity of the wound is the more important factor in determining death and disability. It would be desirable, however, to have data which include a count of the actual number of wounds by anatomic region in both the living and the dead.

TABLE 89.—*Disposition of patients with multiple wounds as related to number of anatomic regions hit and to severity of wounds, by causative agent*

Causative agent	Patients				Anatomic regions hit in patients—			
	Returned to duty from first echelon [1]	Returned to duty from rear echelon [2]	Evacuated to United States	Total	Returned to duty from first echelon [1]	Returned to duty from rear echelon [2]	Evacuated to United States	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Mortar	53	41	33	127	117	99	85	301
Grenade	29	16	11	56	70	40	29	139
Landmine	2	7	5	14	4	20	16	40
Artillery shell	4	6	3	13	9	12	8	29
Rifle	2	7	3	12	4	17	7	28
Machinegun	------	1	3	4	------	3	8	11
Total	90	78	58	226	204	191	153	548

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

TABLE 90.—*Ratio of number of anatomic regions hit per patient evacuated in each echelon, by causative agent*

Causative agent	Returned to duty from—		Evacuated to United States	Total
	First echelon [1]	Rear echelon [2]		
Mortar	2. 21	2. 41	2. 58	2. 37
Grenade	2. 41	2. 50	2. 64	2. 48
Landmine	2. 00	2. 86	3. 20	2. 86
Artillery shell	2. 25	2. 00	2. 67	2. 23
Rifle	2. 00	2. 43	2. 33	2. 33
Machinegun	-----------	3. 00	2. 67	2. 75
Total	2. 27	2. 45	2. 64	2. 44

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

Relative Lethal Effect of U.S. Weapons and Japanese Weapons

It had been the intention of the survey team to study the effect of U.S. weapons on the enemy dead. Unfortunately, this plan was found impracticable because of difficulty in obtaining the enemy dead before decomposition had occurred and also because of the paucity of team personnel. Certain local conditions prevailed which circumvented accuracy in such a study. In the first place, because of the character of the fighting and the extensive use, by Allied forces, of artillery and mortar fire, the enemy dead were frequently struck by many different missiles before the bodies could be recovered. Furthermore, it was impossible to obtain any detailed information regarding the circumstances surrounding death.

It was possible, however, to investigate the effect of U.S. weapons on a limited number of American soldiers who were wounded (table 91). There were 219 casualties (12.3 percent of the total) due to U.S. weapons in the hands of American troops. Though the Japanese used some U.S. weapons, particularly rifles and grenades, as a rule it was impossible to know when this occurred. Among Allied forces, there were 63 deaths (16.0 percent of the total dead) produced by U.S. weapons.

There were 52 casualties caused by the rifle, 16 of whom died (table 92); 19 were wounded by the accidental discharge of a rifle by a fellow soldier. Mistaken identity resulted in 13 deaths and the wounding of 6 others. Of these deaths, 8 were occasioned by the soldier seeking to relieve himself at the toilet during the night. Self-inflicted wounds, accidental or intentional, were responsible for 10 casualties, 3 of whom died. Mortar and artillery fire accounted for 54 of the wounded and 22 of the dead. Among these, 13 were killed and 40 wounded by mortar and artillery "shorts." Among the 16 casualties who were

wounded on patrol by U.S. artillery, 8 died. The accidental tripping of landmines and boobytraps produced 14 deaths in a total of 40 wounded. Hand grenades, other than those used in boobytraps, were responsible for 8 deaths and 4 wounded. Miscellaneous weapons including bangalore torpedoes, bombs, pistols, knives, and powder explosions accounted for 38 casualties; 7 of these casualties died.

TABLE 91.—*Distribution of 219 U.S. casualties produced by U.S. weapons, by category*

Category	Casualties	
	Number	Percent
Dead:		
Killed in action	48	22.0
DOW (died of wounds)	15	6.8
Total	63	28.8
Wounded, living:		
Evacuated to United States	25	11.4
Returned to duty from—		
First echelon [1]	85	38.8
Rear echelon [2]	46	21.0
Total	156	71.2
Grand total	219	100.0

[1] Defined as the beachhead perimeter on Bougainville Island.
[2] From hospitals on Guadalcanal, Espíritu Santo, and New Caledonia.

TABLE 92.—*Relative lethal effect of U.S. weapons on 219 U.S. casualties*

Weapon	Total casualties		Dead		Living wounded	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Rifle	52	23.7	16	30.8	36	69.2
Machinegun	1	.5	1	100.0		
Mortar	34	15.5	5	14.7	29	85.3
Artillery	42	19.2	17	40.5	25	59.5
Grenade	19	8.7	5	26.3	14	73.7
Mine	33	15.1	12	36.4	21	63.6
Miscellaneous	38	17.3	7	18.4	31	81.6
Total	219	100.0	63	28.8	156	71.2

[1] Percent for dichotomy, dead versus living, by each causative agent and for total dead versus living.

Though the number of casualties just cited was too small to allow adequate comparison between the effect of Japanese and U.S. weapons, it was the only available data and has been utilized (tables 92 and 93). It is evident that the relative lethal effects of the Japanese mortar and rifle are essentially similar to the lethal effects of these same U.S. weapons. However, the relative lethal effect of U.S. artillery is 40.5 percent, while that of the Japanese artillery is only 17.8 percent. A possible explanation for this discrepancy may lie in the proportion of different weapons employed by the opposing forces. The predominant Japanese artillery piece was the 75 mm. gun, whereas most of U.S. artillery weapons were 105 mm. or larger caliber. In relative lethal effects, a sharp contrast is observed between the U.S. grenade, 26.3 percent, and the Japanese grenade, 4.4 percent (fig. 183). This finding is in accord with the generally observed ineffectiveness of the Japanese grenade.

TABLE 93.—*Relative lethal effect of Japanese weapons on 1,569 U.S. casualties*

Weapon	Total casualties		Dead		Living wounded	
	Number	Percent	Number	Percent [1]	Number	Percent [1]
Rifle	393	25. 0	127	32. 3	266	67. 7
Machinegun	150	9. 6	86	57. 3	64	42. 7
Mortar	659	42. 0	77	11. 7	582	88. 3
Artillery	152	9. 6	27	17. 8	125	82. 2
Grenade	205	13. 0	9	4. 4	196	95. 6
Mine	1	. 1	1	100. 0		
Miscellaneous	9	. 6	5	55. 6	4	44. 4
Total	1, 569	100. 0	332	21. 2	1, 237	78. 8

[1] Percent for dichotomy, dead versus living, by each causative agent and for total dead versus living.

TREATMENT OF THE WOUNDED

A detailed clinical study would be out of place in a report on wound ballistics. On the other hand, a résumé of end results in the treatment of the wounded is essential to the proper evaluation of the effect of weapons. This is well illustrated by the results obtained in the treatment of compound fractures of the femur early in World War I, when the mortality at first was 50 percent. Such a mortality would materially change the evaluation of the effect of weapons causing wounds in the lower extremities.

The purpose of this section on the treatment of the wounded is to indicate the quality of the treatment, good or bad; to account for all of those wounded in action and who died later; to record the amount of disability as indicated by the disposition of the patients; and to give a very brief classification of the

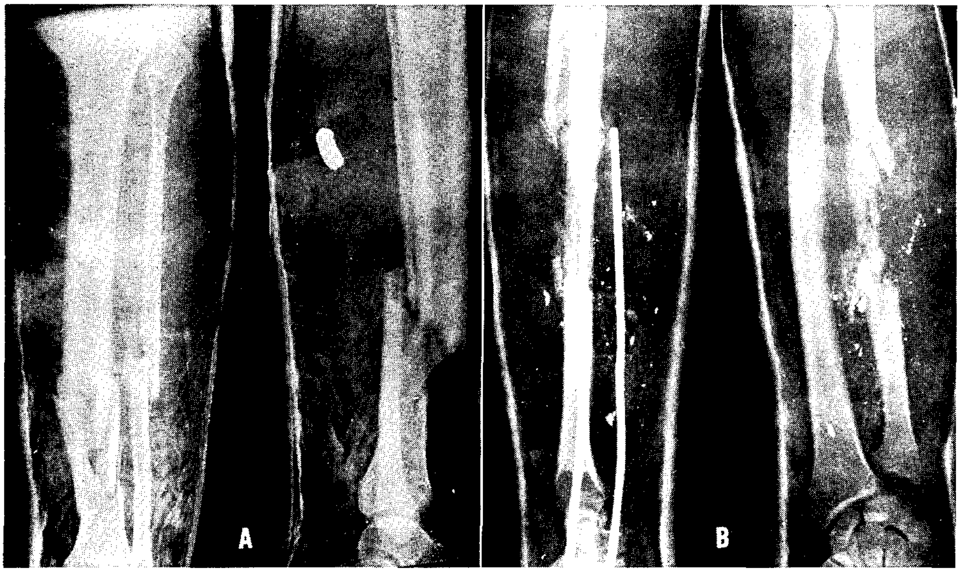

FIGURE 183.—Roentgenograms of lower and upper extremities. A. Lower extremity wound caused by a U.S. hand grenade thrown by a Japanese. The grenade exploded 3 yards from the leg. The typical large fragment is shown. B. Fracture of the ulna and the usual small fragments characteristic of the Japanese hand grenade. The soldier was lying in a foxhole, and the grenade exploded almost in contact with the arm. Under these circumstances, there may be considerable brisance effect on the soft tissues.

types of wounds encountered in the various anatomic regions. A recording of the circumstances on how each wound was acquired and even a brief description of the wound would make this section far too lengthy. On the other hand, such descriptions are helpful in giving the reader an appreciation of the type of warfare encountered. For this reason, a brief description is given of the circumstances associated with the wounding of each patient who was wounded in action and died later.

Wounds of the Head and Neck

There were 250 patients [13] with wounds of the head and neck alone who were seen alive (table 67); 10 of this number (4 percent) died. These 10 patients were considered as mortally wounded, and 7 died without operation (Cases 1 to 7). Three patients died following operation, making an operative mortality for all head and neck wounds of 1.2 percent (Cases 8, 9, and 10).

Of these 250 patients, 198 had wounds of the scalp, face, and neck. There were 55 patients who had injuries of the eye, 19 of whom (35.5 percent) were

[13] There were 90 patients listed under multiple wounds who also had wounds of the head and neck. However, these wounds did not constitute major problems of the head and neck, and, in order to avoid duplication, such patients were considered only under multiple wounds.

returned to the United States because of permanent visual impairment. The most serious wounds encountered in the group of face and neck injuries were 4 perforations of the trachea, 9 compound fractures of the mandible, and 4 of the maxilla. The majority of face and neck wounds were not serious, and 86.6 percent of the patients who received such wounds were returned to duty within 4 months. There were 52 patients who sustained brain injury; 27 of these had concussion, and 3 were evacuated to the United States.

Of the remaining 25 patients who had brain injury, 9 were mortally wounded. Nineteen of these patients underwent operation and three died, making a mortality of 15.7 percent. All three of these patients may be considered as having been mortally wounded (Cases 8, 9, and 10). Among the 19 cases having operation, the dura was open and the brain lacerated in 14, and in 5 there were depressed fractures without opening of the dura.

CASE REPORTS: WOUNDED-TREATED-DIED-LATER

Head and neck wounds

Case 1.—A Fijian soldier, while on patrol, was wounded by a fragment of a U.S. 90 mm. shell which exploded at a 20-yard distance, at 1700 hours on 30 March 1944. At the 21st Evacuation Hospital, he was found to have a penetrating wound of the skull through the right frontal bone with extensive laceration of the brain and severe intracranial hemorrhage. He died shortly after arrivai, at 2000 hours on 30 March 1944, of respiratory failure and extensive brain damage. (See autopsy protocol Case 3, p. 381.)

Case 2.—A Fijian soldier, while on patrol, was struck by a U.S. 90 mm. shell fragment 25 yards from the burst at 1700 hours on 30 March 1944. He received a penetrating wound of the head in the right temporal region and was taken directly to the 21st Evacuation Hospital. The patient was moribund and died at 1855 hours on 30 March 1944. (See autopsy protocol Case 12, p. 386.)

Case 3.—A soldier of the 145th Infantry, 37th Division, was struck in the head by a Japanese machinegun bullet fired from a distance of 30 yards at 1250 hours on 9 March 1944. He was given first aid, including plasma, but never regained consciousness and died in the battalion aid station 2 hours later.

Case 4.—A Fijian soldier was mistaken for the enemy and shot in the head and abdomen by a U.S. .30 caliber rifle at a distance of 15 yards. He was wounded at 1810 hours on 23 March 1944 and taken directly to the 21st Evacuation Hospital. Examination disclosed a severe gutter wound of the right side of the head with extensive brain damage and a wound of the abdomen. He was given 1 unit of plasma but, being moribund, died at 2055 hours on 23 March 1944. (See autopsy protocol Case 22, p. 390.)

Case 5.—A soldier of the 182d Infantry, while withdrawing from enemy fire, was hit in the back of the neck by a .25 caliber Japanese bullet fired by a sniper from a distance of 35 yards. He was wounded at 0600 hours on 15 March 1944, kept in the battalion aid station about 2 hours, and then taken to the 21st Evacuation Hospital. He was paralyzed and in shock and no operation was done. His death was associated with hyperthermia and occurred at 1300 hours on 15 March 1944. The clinical impression was transection of the cervical cord at the level of cervical fifth vertebra, but post mortem revealed that the cord had not been penetrated. (See autopsy protocol Case 21, p. 388.) (NOTE.—This was the only instance of trauma to the spinal cord in which the dura was intact.)

Case 6.—A soldier of the 145th Infantry, 37th Division, was struck by fragments of a mortar shell which exploded in a tree 15 feet overhead. He sustained multiple wounds of the head and shoulder and a partial avulsion of the leg. A tourniquet was applied to the leg,

plasma was given, and the patient was removed from the lines within an hour. He died on the way to the hospital. Death was thought to have been due to head injury.

Case 7.—A soldier of the 129th Infantry, 37th Division, was wounded by a .25 caliber bullet fired by a Japanese sniper from a distance of 75 yards. The bullet passed through the helmet producing a severe gutter wound of the right parieto-occipital region. The injury occurred at 1430 hours on 24 March 1944. The patient received aid promptly and was given 9 units of plasma before arriving at the 21st Evacuation Hospital. He was mortally wounded, however, and died at 1920 hours on 24 March 1944 without operation. (See autopsy protocol Case 25, p. 391.)

Case 8.—A soldier of the 145th Infantry, 37th Division, was struck by a Japanese machinegun bullet fired from a distance of 30 yards on Hill 700. Because the road was under enemy fire, a 1,000-yard litter carry was necessary over very rough terrain. He was given plasma at the aid station but arrived at the hospital in a semiconscious condition. He had a gutter wound of the left frontotemporal region and a severe laceration of the brain. The wound was debrided and shock treatment instituted, but the patient died 24 hours later. Death was due to extensive brain damage.

Case 9.—A soldier of the 129th Infantry, 37th Division, was struck by a fragment of a Japanese mortar shell (90 mm.) which burst 20 feet distant at 0630 hours on 17 March 1944. He was removed to the aid station at 0830 hours and thence to the 21st Evacuation Hospital. He had a gutter wound of the right temporal region which measured 4×2 inches and a deep laceration of the brain measuring 2×2×2 inches. Though the patient appeared to be mortally wounded, a sanguine attempt was made to control hemorrhage. In spite of supportive treatment, the patient died at 2000 hours on 17 March 1944 with hyperthermia. (See autopsy protocol Case 26, p. 391.)

Case 10.—A soldier of the 145th Infantry, 37th Division, was struck by a fragment of a Japanese mortar shell which burst 3 yards distant at 1800 hours on 10 March 1944. He was evacuated promptly to the 21st Evacuation Hospital and found to have a severe wound penetrating the right eye and base of the skull with intracranial hemorrhage. In spite of supportive treatment, he died at 2400 hours on 10 March 1944. (See autopsy protocol Case 23, p. 390.)

Wounds of the Thorax

A discussion of wounds of the thorax is complicated by the fact that frequently the causative missiles pass through the diaphragm causing wounds of abdominal organs which in turn may be responsible for the death of the patient. For this reason, wounds involving both the thorax and abdomen are discussed in a separate section. Multiple wounds present a special problem, since they include many wounds of the thorax, and they also are discussed in a separate section. Included under multiple wounds were 62 wounds of the thoracic wall alone and 3 wounds perforating the lung. None of these patients died, and the three perforating wounds were treated conservatively.

Excluding the groups previously mentioned, there were 156 patients with wounds of the thorax who were seen alive. Thirteen of these patients died, giving a mortality of 8.3 percent; the operative mortality for the entire group, however, was much lower since seven of these patients died of shock and hemorrhage without operation (Cases 1 through 7).

Wounds of the thorax may be divided into two general groups, those involving the chest wall only and those perforating the thoracic cage. There were 102 patients (65.4 percent) who had wounds limited to the thoracic

wall. None of these patients died. The majority of these had penetrating wounds caused by small fragments from HE shells. Only 10 of these patients (9.8 percent) were evacuated to the United States and the remainder returned to duty.

There were 54 patients with perforating or lacerating wounds of the lung who were seen alive. All 13 deaths occurred in this group, making a mortality of 24.1 percent. Eighteen of these patients were known to have had sucking wounds. There were 29 open operations on the chest with 6 deaths, an operative mortality of 20.7 percent (Cases 8 through 13). Eighteen patients with penetrating or perforating wounds were treated conservatively with debridement only. There were no deaths in this group. The total operative mortality for perforating or lacerating wounds of the lung was 12.7 percent; 47 patients underwent operation and 6 died.

CASE REPORTS: WOUNDED-TREATED-DIED-LATER

Thoracic wounds

Case 1.—A soldier of the 246th Field Artillery Battalion, Americal Division, was riding in the back of an uncovered truck when a Japanese 105 mm. shell exploded at a distance of 5 yards to the rear, at 0730 hours on 8 March 1944. He was struck by a shell fragment which caused a large wound of the posterior aspect of the left side of the chest. He was taken immediately to a battalion aid station, a dressing applied, and plasma given. He did not recover from shock, however, and died at 1120 hours on 8 March 1944.

Case 2.—A soldier of the 148th Infantry, 37th Division, was lying prone on the ground when a mortar shell exploded at a distance of 2 feet at 0800 hours on 12 March 1944. On arrival at the 21st Evacuation Hospital 50 minutes later, he was moribund with multiple wounds of the left side of the jaw, upper right arm, and profuse hemorrhage from a large perforating wound which extended through the right shoulder into the chest cavity. He was mortally wounded and died without treatment at the hospital at 0910 hours on 12 March 1944.

Case 3.—A soldier of the 182d Infantry, Americal Division, was manning a machinegun in a foxhole on Hill 260. This soldier slipped out to look for the enemy position and was struck by a fragment of a Japanese mortar shell which burst at a distance of 40 yards. He received multiple severe wounds of the left side of the chest and of the left arm and did not regain consciousness. While in the battalion aid station, he died from hemorrhage at 1300 hours on 11 March 1944.

Case 4.—A soldier of the 182d Infantry, Americal Division, was advancing in an upright position in a skirmish line on Hill 260 when he was struck by Japanese .25 caliber machinegun bullets at 1430 hours on 10 March 1944. He received multiple wounds of the chest and arm, was given first aid which included plasma, but died at the collecting company at 1530 hours on 10 March 1944.

Case 5.—A soldier of the 145th Infantry, 37th Division, was standing in a covered foxhole by a machinegun when he was hit by a Japanese mortar fragment at a distance of 5 yards from the burst. The shell fragment penetrated the soldier's left shoulder and entered the chest. He received immediate first aid, including plasma, at the aid station. The wounding occurred at 0545 on 12 March 1944, and the patient died in the aid station of pulmonary hemorrhage 3 hours later.

Case 6.—A soldier of the 129th Infantry, 37th Division, was advancing behind a tank when he was wounded by a Japanese .25 caliber machinegun bullet fired from a distance of 25 yards at 1245 hours on 24 March 1944. The bullet entered the chest and transected the

spinal cord. His death at the 21st Evacuation Hospital 24 hours later was accompanied by shock and hyperthermia. (See autopsy protocol Case 52, p. 398.)

Case 7.—A soldier of the 132d Infantry, Americal Division, was wounded by a shell fragment from a U.S. artillery "short" at 0815 hours on 7 April 1944. The distance from the burst was unknown. A large sucking wound of the left side of the chest and multiple penetrating wounds of the left thigh were evident. He died in the clearing station at 1145 hours on 7 April 1944, as a result of severe hemorrhage from the chest wound.

Case 8.—A Fijian soldier was crouching on patrol when he was struck by a .25 caliber Japanese sniper bullet fired from a distance of 30 yards. An extensive wound of the lower part of the left side of the chest was accompanied by profuse hemorrhage. On arrival at the 21st Evacuation Hospital, it was evident that fatal exsanguination was imminent; accordingly, an immediate but futile attempt was made to relieve intrathoracic pressure and to control hemorrhage. During operation, the patient was given 1,500 cc. of whole blood and 6 units of plasma, but he died on the operating table. (See autopsy protocol Case 56, p. 400.)

Case 9.—A soldier of the 182d Infantry, Americal Division, was lying prone on Hill 260 operating a machinegun when he was hit by a .25 caliber Japanese machinegun bullet fired from a distance of 50 yards at 1200 hours on 12 March 1944. He sustained a sucking wound of the lower part of the right side of the chest accompanied by multiple fractured ribs posteriorly and disruption of the rib cartilages anteriorly. At the 31st Portable Surgical Hospital, 2,000 cc. of plasma and 1,200 cc. of whole blood were administered and the skin rapidly closed over the sucking wound. After transfer to the 21st Evacuation Hospital, the patient continued to have severe respiratory difficulty because of the crushing chest wound. An attempt was made to reconstruct the posterior thoracic cage by wiring the fourth, fifth, sixth, seventh, and eighth ribs to their paravertebral stumps. At operation, the lung was stated to have the appearance of "blast injury" [14] (consolidation). There were several rents in the lung but no bleeding. On 14 March 1944, it was apparent that the patient had pneumonia, his temperature had risen to 106° F., and his respiratory rate to 50. Accordingly, 100,000 units of penicillin were given. The paradoxical breathing due to the disrupted anterior cartilages became worse, and the patient died of respiratory failure at 2300 hours on 14 March 1944.

Case 10.—A soldier of the 129th Infantry, 37th Division, was prone on the crest of a ridge behind a tank attack when he was hit by a .25 caliber Japanese rifle bullet fired from a distance of 100 yards. He received a severe wound of the posterior aspect of the left side of the thorax, at 1100 hours on 24 March 1944, and was removed at once to the 21st Evacuation Hospital. At operation, the lacerated lung was repaired and the wound closed tightly. On the following day, because of the development of pneumonia, penicillin therapy was instituted, using 25,000 units every 4 hours. A severe right pneumothorax was aspirated. On 26 March, the patient's temperature was 105° F. and his condition poor. Slight improvement occurred, but on 28 March the patient suddenly cried out, ceased breathing, and died at 0730 hours. The radial pulse was perceptible for a brief interval after respiration ceased. A diagnosis of pulmonary embolism was made. (See autopsy protocol Case 50, p. 398.)

Case 11.—An airman of the Thirteenth Army Air Force accidentally shot himself with a .30 caliber carbine at 1300 on 4 April 1944. The bullet perforated the left side of the chest. He was taken immediately to the 52d Field Hospital and given 3 units of plasma. At operation 2 hours later, the patient died on the table. The cause of death was not entirely clear, although a large intrapleural hemorrhage may have been sufficient to account for the fatal termination. A contusion of the heart muscle was found at post mortem. (See autopsy protocol Case 53, p 399.)

[14] This type of pulmonary hemorrhage is seen with the large temporary cavity produced by the passage of high-velocity missiles. The term "blast injury" is used rather frequently throughout the case reports, and in most instances, especially where it is associated with small arms wounds, the pulmonary damage is related to the temporary cavity effect. Small patchy areas of pulmonary hemorrhage are related to blood aspiration.—J. C. B.

Case 12.—A soldier of the 129th Infantry, 37th Division, was standing by his foxhole when he was struck by a fragment of a 4.2-inch U.S. mortar shell which fell short and burst at a distance of 7 feet. At the 33d Portable Surgical Hospital, a sucking wound of the right side of the chest was sutured. Since this hospital had no thoracic surgeon, the patient was transferred to the 21st Evacuation Hospital. En route, severe bleeding occurred because of dehiscence of the recently sutured thoracic wound. While 1,500 cc. of blood and 10 units of plasma were being administered, a second operation was done. A rib fragment was removed from the lung and active bleeding of the intercostal arteries controlled. The wound was closed tightly with through-and-through sutures. At the termination of the operation, the blood pressure was 80/50. A penicillin solution containing 17,500 units was left in the pleural cavity. The patient did not recover consciousness and died at 1500 hours on 30 March 1944. Autopsy showed acute dilatation of the heart, hemorrhage in the right lung and right hemothorax. (Note.—Interhospital transfer of this patient was obviously inadvisable.)

Case 13.—A soldier of the 182d Infantry, Americal Division, was moving up a hill when he was struck by a .25 caliber Japanese bullet fired from a distance of 30 yards at 1130 hours on 20 March 1944. The bullet fractured the posterior portion of the ninth rib, perforated the upper lobe of the right lung, and made its exit in the right supraclavicular fossa. Sucking wounds were present on the posterior and anterior aspects of the chest, with free bleeding from the posterior wound. At the 31st Portable Surgical Hospital, plasma was given, and the sucking wounds were debrided and closed. The lung appeared consolidated from intrapulmonary hemorrhage. The patient died of shock and hemorrhage shortly after operation.

Wounds of Thorax and Abdomen

The anatomic divisions of thorax and abdomen are satisfactory for a consideration of wounds of entrance. From a clinical standpoint, however, those wounds which are caused by missiles which pass from one cavity into the other present special problems of sufficient importance to warrant placing them in a separate category.

There were 24 patients with wounds in which the missile penetrated both the thoracic and abdominal cavities. More than half of these wounds were caused by bullets entering the chest. The various missiles entered through the thorax in 17 cases; through the abdomen, in 4; and through both the abdomen and chest, in 3. Bullets caused 16 of these wounds; mortar fragments, 5; and artillery shell fragments, 3.

The mortality of these wounds is higher than for wounds of the thorax or abdomen alone. Of the 24 cases, 18 died, resulting in a mortality of 75.0 percent. Three of these patients died of hemorrhage and shock without operation. Twenty-one patients underwent operation; of these, 15 died, giving an operative mortality of 71.4 percent. Brief case histories are given for all patients who were wounded in action and died later.

The high operative mortality requires some further explanation. If medical installations had not been so easily available, some of these patients probably would have been classed as killed in action. Shock from hemorrhage was usually severe, and occasionally, when bleeding continued, it was necessary to attempt "heroic surgery" (Case 5) in an effort to control it. Bleeding into both the thorax and abdomen resulting from explosive wounds

of the liver, spleen, and kidney frequently contributed to the shock. On the whole, anesthesia appeared to have been well done but occasionally left something to be desired. More whole blood would have been beneficial in some instances, since blood loss was frequently great and could be replaced by plasma only within limits. Hemorrhage and shock were the chief causes of death as seen in Cases 5, 6, 8, 10, 11, 14, 16, 17, and 18. Case 15 was moved immediately after operation. This may have contributed to the shock. Case 4 illustrates the sequelae which may be encountered from the temporary cavity effect due to high-velocity bullets. Case 12 died with uremia associated with a high sulfathiazole blood level. (This patient also had an explosive wound of one kidney.) Extensive liver damage appeared to account for one death (Case 7). Two patients who were evacuated to the rear echelon died; one from sepsis and empyema (Case 9) and the other from secondary hemorrhage (Case 13). The strain of evacuation may have contributed to death in these cases.

CASE REPORTS: WOUNDED-TREATED-DIED-LATER

Thoracic and abdominal wounds

Case 1.—A soldier of the 132d Infantry, Americal Division, was running between foxholes on Hill 260 when he was shot by a .25 caliber rifle at 40 yards. The bullet entered the thorax at the level of the left seventh rib in the anterior axillary line. He was wounded at 1530 hours on 14 March 1944. Within 15 minutes after receiving first aid, he was taken to the aid station and from there transferred directly to the 31st Portable Surgical Hospital. The wound was extensive as the bullet had passed tangentially from the thorax into the abdomen and had lacerated the left lung, perforated the diaphragm, and had produced a massive hemothorax. The spleen was shattered, gastrosplenic artery and renal vein divided, and entire descending colon avulsed. Because he was mortally wounded, the patient was given supportive treatment only. He died at 0515 hours on 15 March 1944.

Case 2.—A soldier of the 145th Infantry, 37th Division, was souvenir hunting when he was hit by a .25 caliber Japanese rifle bullet fired from a distance of 70 yards. He was in severe shock when first seen at 1420 hours on 12 March 1944. At the aid station, he was given 3 units of plasma and then transferred to the clearing station. The bullet had entered the posterior aspect of the left side of the chest and had produced a large wound of exit in the left upper quadrant of the abdomen from which omentum protruded. He did not respond to therapy and died in the shock tent at 1700 hours on 12 March 1944.

Case 3.—A soldier of the 82d Chemical Battalion, supporting the 37th Division, was standing in a pit beside his mortar when a Japanese 81 mm. mortar shell exploded 4 yards distant at 1930 hours on 8 March 1944. He was taken directly to the 21st Evacuation Hospital and on arrival was found to be in profound shock from multiple wounds of the thorax and abdomen and both lower extremities. A severe compound fracture of the left femur was present. He did not respond to shock therapy and died without operation at 0530 hours on 9 March 1944. Death resulted from hemorrhage, shock, and respiratory failure. Cursory post mortem examination revealed multiple penetrating wounds of the left side of the chest and abdomen involving the large bowel.

Case 4.—A soldier of the 129th Infantry, 37th Division, was prone on the ground in front of the tanks when he was shot by a .30 caliber Japanese machinegun at a 35-yard distance. He was struck by two bullets in the back, at 0830 hours, and taken directly to the 21st Evacuation Hospital. He had an obvious left hemothorax, a sucking wound of the chest, and questionable abdominal involvement. After preliminary shock treatment,

the explosive wound of the chest was debrided and closed. The abdomen was then opened, but no lesion was found. He responded well to operation but developed increasing respiratory difficulty requiring frequent aspiration and died at 0645 hours on 28 March 1944. (See autopsy protocol Case 54, p. 399.)

Case 5.—A soldier of the 145th Infantry, 37th Division, was among a group of men preparing to climb into a truck when four shells struck within a radius of 15 yards at 0730 hours on 18 March 1944. This man received first aid immediately and arrived at the 21st Evacuation Hospital within an hour. He had a large sucking wound of the posterior aspect of the chest with a laceration of the lower lobe of the left lung, perforation of the diaphragm, and laceration of the spleen and cardia of the stomach. He received 2,000 cc. of blood and 8 units of plasma within 6 hours but neither regained conciousness nor recovered from shock. Thoracotomy was necessitated because of continued intrathoracic bleeding which produced a shift of the mediastinum. At operation, 3,000 cc. of blood were removed from the pleural cavity and lacerations in the lung and dome of the diaphragm were repaired. In spite of continuous shock therapy, recovery was not sufficient to allow repair of the abdominal defects. He died at 0545 hours on 19 March 1944. (See autopsy protocol Case 74, p. 406.)

Case 6.—A soldier of the 24th Infantry, 93d Division, was prone on the ground on a combat patrol when he was shot by a .30 caliber Japanese machinegun from a distance of 30 yards. He received multiple wounds. At 1000 hours on 19 April 1944, he was given first aid and arrived at the 52d Field Hospital at 1400 hours. In order to combat severe shock, he was given 1,000 cc. blood and 1,250 cc. of plasma. Because of suspected lung hemorrhage, thoracotomy was performed. A bone fragment was removed from the lung and the pleura and diaphragm were sutured. He did not respond to shock therapy and died at 2125 hours on 19 April 1944. (See autopsy protocol Case 73, p. 406, for description of multiple wounds.)

Case 7.—A soldier of the 145th Infantry, 37th Division, was climbing a hill when he was hit by a .25 caliber Japanese sniper bullet fired from a distance of 30 yards. He was wounded at 1745 hours on 11 March 1944, given first aid, and taken directly to the 21st Evacuation Hospital. After adequate shock therapy, thoracotomy was performed. The lower lobe of the right lung was lacerated and showed consolidation, the eighth and ninth ribs were shattered, and in addition a rent in the diaphragm and a severe explosive wound of the liver were discovered. The lung was sutured, the diaphragm transplanted, and the liver packed. Death occurred at 1600 hours on 15 March 1944, prior to which time recovery had seemed satisfactory. Post mortem examination showed no cause of death other than extensive liver damage.

Case 8.—A soldier of the 57th Engineer Combat Battalion, Americal Division, was accidentally shot by a .30 caliber M1 rifle, at 1300 hours on 22 February 1944, at a 1-foot distance. After receiving immediate first aid and plasma, he was taken to the 52d Field Hospital. A large sucking wound of the right side of the chest was present. Because of continued hemorrhage, plasma and 1,000 cc. of blood were administered during operation. Thoracotomy revealed a perforation of the diaphragm and explosive wound of the liver and large hemothorax. An attempt was made to control bleeding from the liver by packing it with muscle. The patient died of shock and hemorrhage, a half hour after the conclusion of the operation, at 1615 hours on 22 February 1944.

Case 9.—A soldier of the 145th Infantry, 37th Division, was kneeling, when he was shot by a .25 caliber Japanese rifle at 15 yards, on 16 March 1944. A sucking wound of the lower portion of the right side of the chest resulted. After blood and plasma transfusions, the thorax was explored at the 21st Evacuation Hospital. It was found that the bullet had perforated the lower lobe of the left lung, guttered a large wound in the diaphragm, and transected the spinal cord at the level of the 12th dorsal vertebra. A right lower lobectomy was done and the diaphragm repaired. He was evacuated to the rear echelon in good condition on the eighth postoperative day. Later, he developed empyema and, in spite of

adequate drainage and penicillin therapy, died on 25 April 1944. (See autopsy protocol Case 55, p. 400.)

Case 10.—A Fijian soldier was mistaken for the enemy and shot by a .30 caliber machinegun at a 30-yard distance. He was wounded at 1500 hours on 1 April 1944 and was evacuated immediately to the 21st Evacuation Hospital. After shock treatment, thoracotomy was done because of suspected hemorrhage. At operation, a right lower lobectomy was performed and an extensive wound in the liver packed. He did not recover from this operation and died at 2030 hours on 1 April 1944. (See autopsy protocol Case 72, p. 406.)

Case 11.—A soldier of the 37th Reconnaissance Troop, 37th Division, was on a combat patrol which was ambushed. He was shot by a .25 caliber Japanese rifle at a 25-yard distance at 1815 hours on 4 March 1944. He received first aid treatment but did not arrive at the hospital until 0800 hours on 5 March 1944. The bullet entered the abdomen through the left flank and made its exit through the anterior aspect of the right side of the chest wall. After shock therapy, perforations of the small and large bowel were sutured. The patient did not recover from shock and died at 1615 hours on 5 March 1944. (See autopsy protocol Case 71, p. 406.)

Case 12.—A soldier of the 132d Infantry, Americal Division, while on combat patrol, was shot by a Japanese rifle as he entered an enemy pillbox at 1700 hours on 29 March 1944. After a long carry, he arrived at the 121st Clearing Station at 2000 hours on 30 March 1944. The bullet had entered the chest in the sixth interspace in the posterior axillary line and had perforated the diaphragm, large bowel, and kidney. At operation, a laceration of the diaphragm was repaired, the large bowel perforation sutured, a transverse colostomy performed, and sulfonamide therapy instituted. On the third day, the urinary output having decreased to 200 cc., a diagnosis of uremia was made. The sulfonamide level was then 24. After transfer to the 21st Evacuation Hospital, he died at 0600 hours on 4 April 1944. (See autopsy protocol Case 68, p. 404.)

Case 13.—A soldier of the 129th Infantry, 37th Division, was shot through the arm and chest by a .25 caliber Japanese rifle bullet on 13 March 1944. After receiving plasma, he was taken directly to the 21st Evacuation Hospital. The bullet had fractured the left humerus, penetrated the chest, perforated the diaphragm, and produced a hemothorax. The wound was debrided and the pleura closed. The patient was evacuated by air on 15 March 1944. He died on 21 March 1944 of secondary hemorrhage. (See autopsy protocol Case 69, p. 405.)

Case 14.—A soldier of the 182d Infantry, Americal Division, was in a foxhole on Hill 260 when he was hit by a .25 caliber Japanese machinegun bullet fired from a distance of 40 yards. He was wounded at 1200 hours on 11 March 1944. At the 31st Portable Surgical Hospital, it was found that the bullet had entered the left side of the chest in the seventh interspace posterior axillary line and had coursed downward and forward into the abdomen. A sucking wound of the chest was closed and the abdomen opened. The bullet had perforated the diaphragm, stomach, and liver, and had shattered the spleen. The various perforations were closed and the spleen removed. The patient did not rally and died at 0700 on 12 March 1944. Autopsy revealed that a perforation of the jejunum had been overlooked at operation. Death was attributed to peritonitis although shock was also a factor.

Case 15.—A soldier of the 182d Infantry was advancing with a combat patrol when he was shot by a machinegun at close range on 8 March 1944. He continued to command for 20 minutes but was then evacuated to the 31st Portable Surgical Hospital. The bullet had entered just medial to the anterior axillary line in the 5th interspace and made exit near the 12th rib posterior. In its course, it had perforated the lung, diaphragm, stomach, and spleen. At operation, the diaphragm and stomach were repaired. The patient was transferred to the 21st Evacuation Hospital on 9 March 1944 and died the following day at 1845 hours. (Note.—The transfer of this patient on the first day after operation was inadvisable.)

Case 16.—A soldier of the 145th Infantry, 37th Division, was struck by a fragment of a Japanese knee mortar shell on Hill 700. He was approximately 25 yards from the burst.

Having received plasma and immediate first aid dressings, he was taken to the 21st Evacuation Hospital. Because of multiple perforating wounds of the chest and abdomen, laparotomy was done. Extensive laceration of the liver and several perforations of the jejunum and duodenum were repaired. He died of shock and hemorrhage on the day of operation at 2240 hours on 11 March 1944.

Case 17.—A soldier of the 920th Air Base Security Battalion was riding on a truck when a Japanese artillery shell exploded 5 feet behind his vehicle at 0600 hours on 24 March 1944. He was taken directly to the 52d Field Hospital and treated for shock. There were two wounds; one traversed the fourth and fifth ribs in the midaxillary line, perforated the lower lobe of the left lung, and entered the posterior mediastinum. The second fragment entered the left ilial region and perforated the sigmoid colon. Massive hemothorax was present. At operation the perforation of the lung was sutured, and the sigmoid colon was exteriorized. The patient was given 4,000 cc. of plasma and 1,000 cc. of whole blood. He did not respond, however, and died 8 hours after the operation. (See autopsy protocol Case 57, p. 400.)

Case 18.—A Fijian soldier was crawling on a combat patrol when a Japanese mortar shell exploded at a distance of 20 yards on 29 March 1944. On arrival at the 21st Evacuation Hospital, he received treatment for shock. Perforating wounds involved the lung, diaphragm, colon, spleen, pancreas, and left kidney; the patient also had a fracture of the left humerus. The spleen was removed, the colon exteriorized, and the diaphragm repaired. He died at 2215 hours on 30 March 1944. (See autopsy protocol Case 70, p. 405.)

Wounds of the Abdomen

This anatomic division is used to designate not only the abdominal cavity and contents but also the various structures surrounding it, including the muscles of the abdominal wall, the vertebral column, and the ilia. Wounds involving both the thorax and abdomen are considered in a separate section.

There were 86 patients who had wounds of the abdomen; in 49 the wounds were limited to the abdominal wall and in 37 they penetrated the abdominal cavity. The majority of wounds limited to the abdominal wall were caused by HE missiles, chiefly mortar fragments. There were 5 deaths among the 49 patients who received wounds of the abdominal wall; only Cases 1 and 2 died before operation. One death followed a negative abdominal exploration (Case 18).

Penetration of the abdominal cavity was found in 37 patients. There were 12 deaths among 36 patients undergoing operation making a total operative mortality of 33.3 percent. However, it must be borne in mind that this high operative mortality is accounted for in part by many mortally wounded patients who died of shock and upon whom operation was undertaken with little hope of success (Cases 5, 7, 10, 11, 12, 13, and 14). One patient died of shock before operation (Case 3), two died of peritonitis (Cases 6 and 8), and one of unexplained uremia (Case 17). No deaths occurred because of failure to explore the abdomen, but in two patients (Cases 4 and 9) death resulted from visceral perforations which were overlooked at operation. The very early evacuation of patients from the portable surgical hospitals undoubtedly contributed to shock and was the factor which may have precipitated death in a few instances (Cases 4, 5, 7, and 17). It is also known that patients do not

tolerate air transportation well soon after abdominal operations, and this type of evacuation may have contributed to the death of one patient (Case 18).

The large bowel was perforated in 15 patients among whom there were 5 deaths, making an operative mortality of 33.3 percent (see Cases 4, 5, 6, 7, 8). Among these 15 patients, the colon alone was perforated in 5, the colon and spleen in 1, and the colon and small intestine in 9. Four of the five deaths occurred in this latter group. The small intestine alone was perforated in 6 patients, the liver in 4, the stomach in 1, and the bladder in 1. All these patients recovered. In addition, three patients recovered who had wounds perforating the abdominal cavity in which the injury was limited to the peritoneum and mesenteric vessels.

CASE REPORTS: WOUNDED-TREATED-DIED-LATER

Abdominal wounds

Case 1.—A soldier of the 145th Infantry, 37th Division, having returned from patrol, was preparing to get into a truck when four Japanese artillery shells landed within a radius of 15 yards. He was wounded at 1930 hours on 18 March 1944 and taken directly to the 21st Evacuation Hospital. Multiple wounds were present which included spinal cord injury and an extensive avulsion of the tissues of the lumbar region exposing the vertebras, spinal canal, and both kidneys. The patient was treated for shock but died without operation at 1300 hours on 19 March 1944.

Case 2.—A soldier of the 145th Infantry, 37th Division, while crawling in attack on Hill 700, was hit by a Japanese machinegun bullet fired from a distance of 30 yards. He was wounded at 0700 hours on 10 March 1944 and arrived at the 21st Evacuation Hospital at 1500 hours on the same day. Extensive compound fractures involving the sacrum, fourth and fifth lumbar vertebras, and the ilium were found. There was apparently no intra-abdominal injury, but the patient failed to recover from profound shock and died at 2330 hours on 11 March 1944.

Case 3.—A soldier of the 132d Infantry, Americal Division, returning from patrol, was shot with a .25 caliber Japanese machinegun at 1600 hours on 6 April 1944. He received first aid and remained in the command post overnight. After receiving plasma, he was evacuated to the clearing station. Multiple wounds involving the lower part of the thorax, abdomen, and sacrum were found. There was no response to shock therapy and death occurred on 8 April 1944. Post mortem examination showed peritonitis, resulting from multiple perforations of the colon and terminal ileum, destruction of fifth lumbar to second sacral vertebras, and retroperitoneal hemorrhage.

Case 4.—A soldier of the 132d Infantry, Americal Division, while walking along a trail on Hill 260, was wounded by a 90 mm. Japanese mortar shellburst 25 yards distant at 1530 hours on 13 March 1944. After immediate first aid treatment, he was taken to the 31st Portable Surgical Hospital. Multiple wounds were present involving the right knee, thigh, right side of the chest, and abdomen. A shell fragment entered the abdomen through the left flank, passed transversely, and perforated the large and small bowel. At operation, the ileum, colon, and mesocolon were repaired. On 15 March 1944, the patient was transferred to the 21st Evacuation Hospital. After the administration of 1,000 cc. of blood and 4 units of plasma, a transverse colostomy was done under local anesthesia because of severe abdominal distention. The patient died at 1115 hours on 16 March 1944. Post mortem examination revealed peritonitis resulting from the two perforations of the jejunum which had been overlooked at operation. (See autopsy protocol Case 83, p. 408.) (NOTE.—Interhospital transfer was inadvisable in this case.)

Case 5.—A soldier of the 37th Division was running along a road carrying a box of ammunition when he was struck by a .25 caliber bullet fired by a Japanese tree sniper from a distance of 75 yards. He was wounded in the abdomen at 0739 hours on 10 March 1944 and transported immediately to the 33d Portable Surgical Hospital. In preparation for laparotomy, he was given 4 units of plasma. At operation, resection of 18 inches of lower ileum with a side-to-side anastomosis was done, and a transverse laceration of the sigmoid colon was sutured. On 11 March, he was transferred to the 21st Evacuation Hospital and died there of shock at 0700 hours on 12 March 1944. (NOTE.—It was inadvisable to have transferred this patient before recovery.)

Case 6.—A soldier of the 82d Chemical Battalion, 37th Division, was standing in the gunpit of a mortar battery when he was struck by fragments of an 81 mm. Japanese mortar shell which burst at a distance of 10 yards. Following wounding at 1930 hours on 8 March 1944, he was removed immediately to the 21st Evacuation Hospital. Severe wounds of the left flank and abdomen involving the sigmoid colon and retroperitoneal tissues were found at operation. The sigmoid colon was exteriorized, but the patient died of peritonitis at 1700 hours on 13 March 1944.

Case 7.—A soldier of the 25th Infantry, 93d Division, was returning from a patrol when he was wounded by a grenade which exploded in his right hand at 1700 hours on 9 April 1944. At the 31st Portable Surgical Hospital, five penetrating wounds of the right side of the abdomen and a compound fracture of the right hand were discovered. Because of the presence of shock, he received 8 units of plasma, 1,000 cc. of blood, and 4,000 cc. of glucose solution. The wounds were debrided and 8 inches of jejunum were resected and 8 perforations of the jejunum were sutured. Perforations of the descending colon, sigmoid colon, and cecum were also repaired and a transverse colostomy done. The patient was transferred to the 21st Evacuation Hospital on 10 April 1944 and died at 2355 hours on 11 April 1944. (See autopsy protocol Case 85, p. 409.) (NOTE.—It was inadvisable to have transferred this patient on the first postoperative day.)

Case 8.—A soldier of the 129th Infantry, 37th Division, while operating a machinegun, was hit by a .25 caliber Japanese sniper bullet, distance unknown, at 1130 hours on 13 March 1944. He received first aid within 20 minutes, was evacuated from the line within 1 hour, and arrived at the 21st Evacuation Hospital shortly thereafter. After appropriate measures to combat shock, laparotomy was done. The bullet, coursing upward after entering the abdomen on the left side, had produced two perforations of the descending colon, severed the right middle colic artery, perforated the jejunum in three places, and then made its exit through the right rectus muscle. The visceral perforations were closed, and after resection of 4 inches of jejunum a catheter was placed in the bowel for decompression. After a few days, severe abdominal distention developed, and it became obvious that the enterostomy was unsatisfactory. The patient died at 1400 hours on 20 March 1944. At autopsy, it was found that the catheter had slipped out of the bowel, probably because the bowel had not been sutured to the abdominal wall. Bile peritonitis produced by leakage was stated to have caused death.

Case 9.—A soldier of the 82d Chemical Battalion, while walking along a column of vehicles which were moving into new positions, was shot without challenge with a U.S. M1 rifle at a distance of 10 feet. He immediately received first aid dressings and plasma and 2 hours later was taken to the 21st Evacuation Hospital. A severe wound of the abdomen was present, and the sigmoid colon was perforated in three places. A bladder wound which was overlooked at the first operation was discovered on the following day. A suprapubic cystotomy was done at once, and at the same operation the left external iliac artery was ligated because of a contused area which had weakened its wall. The patient did not rally, appeared to be in shock, and died at 0344 hours on 16 March 1944.

Case 10.—A soldier of the 145th Infantry, 37th Division, was carrying ammunition to a gun position when a Japanese knee mortar shell burst 10 yards away. He was wounded in the lumbar region at 1330 hours on 10 March 1944 and immediately transported to the 21st Evacuation Hospital. The shell fragment had passed through the left kidney, spleen,

transverse colon, and jejunum. The operation consisted of splenectomy, exteriorization of the transverse colon lesion, and resection of a 3-inch segment of jejunum. Because of the patient's poor condition, nephrectomy was not done. He did not recover completely from shock and died on 14 March 1944.

Case 11.—A soldier of the 82d Chemical Battalion, while standing in a gunpit of a mortar battery, was hit by a fragment of a 77 mm. Japanese mortar shell which burst at a 5-yard distance. He received his wounds at 1930 hours on 8 March 1944 and was taken immediately to the 21st Evacuation Hospital. Following treatment for shock, laparotomy was done. One shell fragment passing laterally had perforated the transverse colon in three places, lacerated the right lobe of the liver, and made an exit wound 4 inches in diameter in the lateral abdominal wall. Present also were a compound fracture of the left ulna and a large wound of the right ankle. There were other smaller wounds of the legs, thighs, buttocks, back, and face. At operation, the wounds were debrided, the perforations of the transverse colon sutured, and the defect in the liver repaired. The patient did not recover from shock and died on the following day at 2330 hours on 9 March 1944.

Case 12.—A soldier of the 132d Infantry, Americal Division, while advancing on Hill 260, was struck by a fragment of a 90 mm. Japanese mortar shell, distance unknown. He was wounded at 0900 hours on 13 March 1944, given immediate first aid, and then transported directly to the 21st Evacuation Hospital. The left arm was avulsed, an extensive wound of the right leg was present, and the great vessels of this extremity were severed. There were multiple wounds of the abdomen, and the ileum was perforated. Because of severe shock, only the perforations of the ileum were sutured at the initial operation. On the following day, because of an extension of gangrene of the leg, amputation was done. The patient died at 2112 hours on 15 March 1944. Post mortem examination showed no leakage from the repaired bowel. In this case, death was attributed to traumatic shock despite the fact that there had been adequate blood replacement. (The surgeon expressed the opinion that the operation should have been postponed and the limb packed in ice.)

Case 13.—A soldier of the 24th Infantry, 37th Division, while on patrol, was struck by a Japanese .25 caliber bullet fired from a distance of 25 yards. While being moved, he was shot again by the same rifleman. This second wound resulted in evisceration. He was wounded at 1030 hours on 16 March 1944 and taken directly to the 21st Evacuation Hospital. There he received 1,000 cc. of blood and 3 units of plasma. The first bullet entered 2 inches below the right costal margin, passed downward along the rectus muscle into the flank, then through the wing of the ileum, and made its exit in the right buttock. The bullet causing the evisceration entered 2 inches below the left costal margin, traveled downward destroying the rectus muscle, perforated the jejunum and ileum, and passed under the inguinal ligament into the thigh. Moderate shock was present. At operation, the eviscerated intestine was enclosed in a pack while the rents in the jejunum and ileum were resected. Profound shock developed from which the patient did not recover, and he died at 1515 hours on 16 March 1944.

Case 14.—A soldier of the 135th Field Artillery Battalion, 37th Division, accompanied a party burying the Japanese dead in front of the 129th Infantry perimeter. He wandered away and was shot by a Japanese .25 caliber rifle at 1545 hours on 27 March 1944. He was taken immediately to the hospital. The bullet entering the lumbar region had shattered the 12th rib, driving bone fragments into the kidney, and had then passed through the right lobe of the liver, causing an extensive laceration. Following appropriate shock therapy, the abdomen was explored and the liver packed. Because of the poor condition of the patient, only the loose fragments of kidney were removed. He did not recover from shock and died at 1830 hours on 27 March 1944. (See autopsy protocol Case 81, p. 407.)

Case 15.—A soldier of the 140th Field Artillery Battalion, 37th Division, while on patrol looking for the enemy who had infiltrated the lines, was shot by a .25 Japanese rifle at a 10-yard distance. He was wounded at 1605 hours on 14 March 1944, received immediate first aid, and arrived at the hospital within an hour. A wound was present in the left axilla, and the axillary vein was severed. The major lesions consisted of compound fractures

of the femur and ileum with an extensive wound penetrating the right hip joint. Severe shock was present. The axillary vein was ligated. Because of the presence of abdominal symptoms, laparotomy was done but no lesion found. During this operation, the urinary bladder was explored and closed. Because of the poor condition of the patient, only a simple debridement of the hip wound was done. The patient showed a severe toxic reaction, developed gas gangrene of the hip, and died on the second postoperative day at 1450 hours on 16 March 1944. (See autopsy protocol Case 103, p. 415.)

Case 16.—A soldier of the 145th Infantry, 37th Division, while attacking on Hill 700, was shot by a Japanese machinegun at 30 yards. He was wounded at 1630 hours on 9 March 1944 and taken immediately to the battalion aid station. After he had received 3 units of plasma, he was evacuated by halftrack because the road was under fire. At the hospital, in order to combat severe shock, he was given 12 units of plasma and 500 cc. of blood. The bullet had entered the right iliac crest and passing downward had shattered the entire right wing of the pelvis. Exploration of the abdomen through a McBurney incision was negative. The hip wound was debrided and packed. He failed to recover from shock and died at 2300 hours on 10 March 1944.

Case 17.—A soldier of the 129th Infantry, 37th Division, was standing by a foxhole when a 4.2-inch U.S. mortar shell fell short and burst 7 feet away, on 27 March 1944. He received treatment for shock at the 33d Portable Surgical Hospital. One shell fragment produced a large wound over the region of the right iliac crest; it also fractured the fifth lumbar vertebra and shattered the lower pole of the right kidney. Another fragment caused a wound of the right shoulder and arm. Shock therapy was continued while the wounds were debrided. The development of severe abdominal distention necessitated ileostomy. On 31 March, he was transferred to the 21st Evacuation Hospital and died there on 1 April 1944 with unexplained uremia. (See autopsy protocol Case 84, p. 409.)

Case 18.—A soldier of the 182d Infantry, Americal Division, was standing in the open when a Japanese hand grenade burst 3 feet away. He was wounded at 1345 hours on 13 March 1944. After arrival at the 31st Portable Surgical Hospital, examination disclosed many wounds over the left side of the trunk and extremities. Following transfer to the clearing station, abdominal exploration was done with negative results. He was evacuated by air on 18 March 1944. On arrival at the 137th Station Hospital on Guadalcanal on the same day, evisceration was discovered. A secondary wound closure was done, but the patient developed peritonitis and died on 25 March 1944. (See autopsy protocol Case 82, p. 408.) (NOTE.—Air evacuation might have caused evisceration, although planes transporting casualties usually fly at low altitudes.)

Wounds of the Extremities

Wounds of the extremities are of great importance because of their frequency. Wounds of the upper and lower extremities together (excluding multiple wounds) accounted for 40.6 percent of all casualties. As a surgical problem, these wounds were of major significance since they comprised more than half of all the living wounded.

Of 320 patients with wounds of the upper extremities, one was killed in action. This patient had a traumatic amputation. There was not a single death in the 319 treated wounds of the upper extremities. Gas gangrene infection did not occur. In this group, there were 119 compound fractures of which 44 were in the humerus, 33 in the bones of the forearm, and 42 in the bones of the hand. There were 10 amputations, 2 through the humerus because of extensive destruction of tissue and impairment of blood supply, 1 traumatic amputation of the hand, and 7 of the fingers.

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There were 401 patients with wounds of the lower extremity (not including multiple wounds), 8 of whom died; 1 of unexplained cause (Case 1); 2 of shock and hemorrhage (Cases 2 and 3); 1 of uremia associated with a probable "crush syndrome nephrosis" (Case 4); 2 not seen by a medical officer, of shock and hemorrhage following traumatic amputations of the feet (Cases 5 and 6); and 2 of gas gangrene (Cases 7 and 8). Therefore, the total mortality for the wounded who were seen alive was 2 percent.

There were 90 compound fractures of the lower extremities distributed as follows: Femur, 23; bones of the leg, 51; and bones of the feet, 16. All fractures were treated with plaster. There were no deaths due directly to compound fracture (Case 4). There were 18 amputations of the lower extremity of which 7 were "traumatic" and 11 elective. Of the 7 traumatic amputations, 3 died (Cases 3, 5, and 6). Of the 11 elective amputations, 8 were done because of extensive tissue destruction and blood vessel injury. The one death in this group occurred in the rear echelon (Case 4). The remaining three amputations were necessary because of gas gangrene infection, although in two of these patients impending circulatory gangrene was also present. One of this group died (Case 8). All amputations were of the guillotine type.

CASE REPORTS: WOUNDED-TREATED-DIED-LATER

Extremity wounds

Case 1.—A soldier of the 132d Infantry, 37th Division, was lying prone in open jungle when he was struck by a .25 caliber Japanese machinegun bullet fired from a distance of 30 yards at 1800 hours on 2 April 1944. He was taken immediately to the battalion aid station and found to have a severe perforating wound of the right knee joint. While receiving first aid treatment, he became hysterical and died suddenly at 1900 hours on 2 April 1944. While some hemorrhage had occurred, he had not lost enough blood to cause severe shock. Death was unexplained.

Case 2.—A soldier of the 132d Infantry, 37th Division, leaving the trail to the observation post to try a "short cut," tripped the wire of a U.S. land mine which exploded a few feet away. He was wounded at 0715 hours on 22 March 1944. Plasma and morphine were administered by a medical officer within 10 minutes, and the patient was immediately evacuated. At the clearing station, examination disclosed an extensive wound of the dorsal aspect of the left thigh. Because of severe hemorrhage from the larger vessels, three blood transfusions were given. Following debridement of the wound and ligation of the profunda artery, the patient did not recover from shock and died at 1500 hours on 22 March 1944.

Case 3.—A soldier of the 129th Infantry, 37th Division, was firing a machinegun when a Japanese knee mortar shell burst between his legs. He was wounded at 1000 hours on 12 March 1944 and taken immediately to the 33d Portable Surgical Hospital. A traumatic amputation at the upper third of the right femur was completed by guillotine amputation under Sodium Pentothal (thiopental sodium) anesthesia, and several small wounds of the posterior aspect of the left leg were dressed. Following operation, during which he received 4 units of plasma, the patient was transferred immediately to the 21st Evacuation Hospital. On arrival there, the systolic blood pressure could not be obtained. While awaiting blood transfusion, he was given 1 unit of plasma but died before this could be completed at 1450 hours on 12 March 1944. Cause of death was shock and hemorrhage. (Note.—This patient should not have been transferred to another hospital.)

Case 4.—A soldier of the 129th Infantry, 37th Division, was lying prone in the open when he was struck by a fragment of a Japanese knee mortar shell which burst nearby. He was wounded on 15 March 1944 and taken to the 21st Evacuation Hospital. He had a severe wound of the right leg involving the vessels and nerves and a compound fracture of the tibia. This wound was debrided. The next day because of destruction of the blood supply a guillotine amputation was done 2 inches proximal to the knee joint. He was evacuated to a station hospital in the rear echelon on 19 March 1944. On 23 March, he developed anuria and died with uremia at 0845 on 25 March 1944. Post mortem examination revealed nephrosis which was thought to have been due to "crush syndrome." (See autopsy protocol Case 93, p. 411.)

Case 5.—A soldier of the 132d Infantry, 37th Division, while on a combat patrol lying in an open foxhole, sustained a direct hit by a Japanese knee mortar shell. He was wounded at 1800 hours on 4 April 1944, was taken to the command post, given 2 units of plasma and morphine, and kept there overnight. He had a traumatic amputation of the right foot. On the following day, an attempt was made to transport this soldier to the hospital, but he died en route while crossing a river at 1300 hours on 5 April 1944. The wound was not bleeding when inspected before the journey, hence a tourniquet was not applied. However, during the long carry, bleeding occurred and death was apparently due to shock from hemorrhage. This might have been prevented by the use of a tourniquet. (See autopsy protocol Case 91, p. 410.)

Case 6.—A soldier of the 182d Infantry, Americal Division, was digging a foxhole on Hill 260 when he was struck in the ankle by a ricochetting .25 caliber Japanese bullet fired from an unknown distance. He was wounded at 1800 hours on 11 March 1944 and received immediate first aid. "There was practically no bleeding when bandaged. It was dark. We put him on a litter and started down the hill." The patient complained of feeling cold, and when the bottom of the hill was reached he was found dead. Profuse hemorrhage had occurred. The rough journey down the hill in the absence of a tourniquet had apparently dislodged a blood clot, thus initiating a fatal hemorrhage.

Case 7.—A soldier of the 182d Infantry, Americal Division, was patrolling on Hill 260 a short distance beyond the perimeter when he tripped the wire of a U.S. grenade boobytrap at 1200 hours on 28 March 1944. He threw himself on the ground but was struck in the left buttock by a fragment at a distance of 3 yards from the burst. He was evacuated immediately to the clearing station and found to have a penetrating wound of the buttocks extending upwards 7 inches into the soft tissues of the lumbar region. The point of entrance was 1 inch in diameter. Through a 3-inch incision, the fragment was removed and the wound closed without drainage. The wound of entrance was debrided but not sutured. The track was not debrided, but the wound was irrigated and dusted with sulfanilamide powder. After transfer to the 21st Evacuation Hospital on 3 April 1944, a diagnosis of gas gangrene was made. Despite the administration of 20,000 units of gas gangrene antitoxin and 1,000 cc. of blood, death occurred 4 hours later as a result of the very virulent *Clostridium welchii* infection.

Case 8.—A soldier of the 37th Division was near Hill 700 prone behind a tree when a Japanese knee mortar shell burst within a few feet. He was wounded at 0430 hours on 11 March 1944 and taken immediately to the battalion aid station. After receiving plasma, he was transferred directly to the 21st Evacuation Hospital. He had multiple severe wounds of both legs, thighs, buttocks, scrotum, and back. Following the administration of an additional 3 units of plasma and 1,000 cc. of blood, wound debridement was done under ether anesthesia. On 13 March 1944, he developed signs of gas gangrene of the right leg and was given 60,000 units of gas gangrene antitoxin. On 14 March, a guillotine amputation of the lower third of the thigh was done, following which the patient became rapidly more toxic and died at 1415 hours on 15 March 1944.

Multiple Wounds

Only those patients who had two or more wounds in different anatomic regions either one of which might have produced death or disability are included in the classification "Multiple Wounds." When a single wound was considered responsible for the disability, even though several additional minor wounds were present, that patient was classified according to the anatomic location of the major wound. Many factors are involved when multiple wounds occur simultaneously in different parts of the body. For this reason, endeavor was made to limit to a minimum the number of casualties included under the division designated "Multiple Wounds." Nevertheless, despite this effort, there were 239 patients seen alive who were so classified.

In this group of 239 patients who received multiple wounds, there were 8 deaths, making a mortality of 3.3 percent. With one exception (Case 3), those who died underwent surgical operation. These operations were usually sanguine procedures, and in most instances death resulted from shock and hemorrhage (Cases 1, 2, 4, 5, 6, and 7). In one patient (Case 8), death was caused by gas gangrene infection.

In these 239 patients, 569 anatomic regions were hit with wounds distributed as follows: Upper extremity, 202 (35.5 percent); lower extremity, 181 (32.0 percent); head, 92 (16.1 percent); thorax, 69 (12.2 percent); and abdomen 25 (4.4 percent). The number of wounds was actually in excess of these figures because several wounds frequently occurred in one anatomic region. There were 2.8 anatomic regions wounded per patient or well in excess of 3 wounds per patient, since many minor wounds from small fragments were not even tabulated.

CASE REPORTS: WOUNDED-TREATED-DIED-LATER

Multiple wounds

Case 1.—A soldier of the Americal Division was struck by a fragment of a shell which burst near him in the messhall at 0730 hours on 11 March 1944. He reached the operating room of the clearing station within 15 minutes and, although shock did not appear to be severe, was given 2 units of plasma. He had sustained a large perforating wound of the left leg, a compound fracture of the bones of the left foot, a wound of the left forearm, a severed temporal artery, and many small penetrating wounds. Following wound debridement, shock supervened, and, despite the administration of 1,500 cc. of blood and 2 units of plasma, the patient died at 1450 hours on 11 March 1944. Death was attributed to irreversible shock, although brain injury may have been a factor since bleeding from the ears was present.

Case 2.—A soldier of the 246th Field Artillery was riding in the back of a truck when a Japanese 105 mm. shell burst 5 yards to the rear at 0730 hours on 8 March 1944. Because hemorrhage was profuse, a tourniquet was immediately applied to the leg and plasma administered. At the nearby 36th Naval Hospital, the patient was treated for shock in association with a severe wound of the left thigh and right forearm and an extensive wound of the back accompanied by compound fractures of the third and fourth lumbar vertebras. The wounds were cleaned, but the patient did not recover from shock and died at 0120 hours on 9 March 1944.

Case 3.—A soldier of the 131st Engineer Combat Battalion, leaving his foxhole to rescue a friend, was struck by fragments of a Japanese 90 mm. mortar shell which burst 6 feet away at 0500 hours on 24 March 1944. He was taken directly to the hospital. It was apparent that the patient was mortally wounded, a blood pressure reading could not be obtained, and profound shock was present. A severe wound involving the brain was found in the temporal region and a penetrating abdominal wound in the region of the right flank. He died without operation at 0830 hours on 24 March 1944. At post mortem, extensive lacerations of the liver and kidney were discovered. (See autopsy protocol Case 99, p. 413.)

Case 4.—A soldier of the 132d Infantry, Americal Division, was investigating a mine field when an M3 antipersonnel mine exploded within a few feet at 0830 hours on 27 March 1944. He received immediate first aid including 3 units of plasma, following which he was removed to the clearing station. A traumatic amputation of the left foot and extensive lacerated wounds of both buttocks and the right forearm were found. Operation under ether anesthesia was started at 1000 hours and completed at 1115 hours. During the operation, 500 cc. of blood and 1 unit of plasma were given, but at the conclusion of the procedure the blood pressure was only 90/60. While recovering from ether, the patient struggled violently and died suddenly at 1455 hours on 27 March 1944. (See autopsy protocol Case 104, p. 415.)

Case 5.—A soldier of the 148th Infantry, 37th Division, was running across a jungle trail when a U.S. 81 mm. mortar shell fell short and burst "right between his legs." He was wounded at 0945 hours on 1 April 1944 and was taken directly to the 33d Portable Surgical Hospital. A traumatic amputation of the right foot, an incomplete traumatic amputation of the left leg, and lacerated wounds of the right elbow and hand were evident. After the administration of 2,000 cc. of blood and 1 unit of plasma, the traumatic amputation of the left leg was completed at operation. The patient died on the operating table at 1500 hours on 1 April 1944. (See autopsy protocol Case 94, p. 411.)

Case 6.—A soldier of the 182d Infantry, Americal Division, was in a slit trench covering a bazooka man when a Japanese knee mortar shell burst in the trench at 0830 hours on 11 March 1944. Both legs were blown off below the knees as well as the left arm and a portion of the right buttock. He received 2 units of plasma, remained rational, and reached the 31st Portable Surgical Hospital with comparatively little bleeding. At operation, the partial amputation of the arm was completed, and the other wounds were debrided. He died at 1300 hours on 11 March 1944 of shock and hemorrhage.

Case 7.—A soldier of the 182d Infantry, Americal Division, while in a foxhole on Hill 260, was wounded by a Japanese knee mortar shell which burst in the foxhole. The aidmen had difficulty in reaching him, and 5 hours elapsed before he could be removed. At the 31st Portable Surgical Hospital, shock was apparent and resulted from compound fractures of the right femur and leg and severe wounds of the right arm, chest, and pelvis. After a plasma transfusion, a Steinmann pin was inserted in the distal end of the femur and the lower leg amputated. The patient did not survive the operation, however, and died at 1350 hours on 13 March 1944. Autopsy showed multiple perforating wounds of the right thigh and a compound fracture of the femur. The right lower leg had been amputated at the junction of the upper and middle thirds, and a compound fracture of the bones of the left foot and deep lacerations of the scrotum, chest wall and medial aspect of the thigh were present. The abdominal and thoracic cavities were negative. Death was attributed to shock and hemorrhage.

Case 8.—A soldier of the 117th Engineer Combat Battalion, 37th Division, while driving a vehicle along a jungle trail, was struck by fragments of a Japanese mortar shell which burst in a tree at a distance of 25 feet. He was wounded at 1030 hours on 9 March 1944 and taken at once to the 21st Evacuation Hospital. Severe multiple wounds of the right thigh and buttocks involving the perineum and scrotum were discovered. The sciatic nerve had been transected. After appropriate shock therapy, the wounds were debrided, and the patient was given a prophylactic injection of 5,000 units of gas gangrene antitoxin. Immediately after a diagnosis of gas gangrene had been established, multiple incisions were

made in affected areas in the right groin and thigh. The patient expired at 2045 hours on 10 March 1944, approximately 30 minutes after the termination of the operation. Death was ascribed to gas gangrene infection.

Comment on Treatment of the Wounded

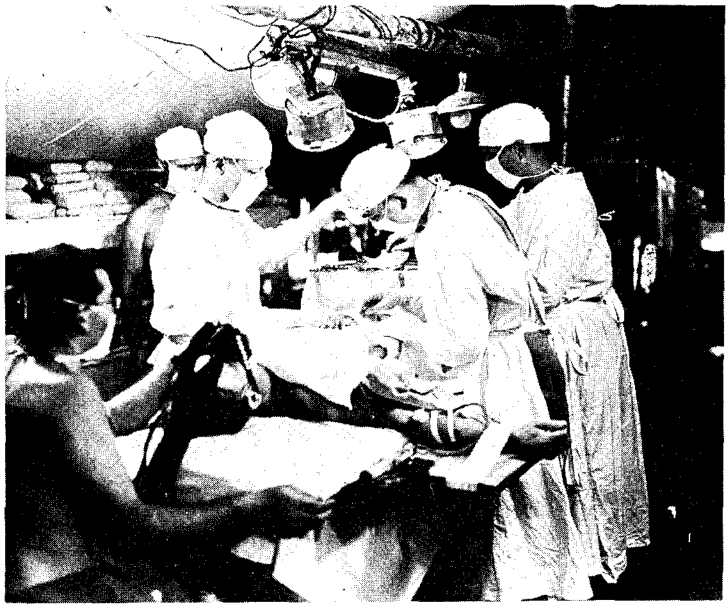
Perhaps never in the history of jungle warfare were professional talent and medical facilities so excellent and routes of evacuation so favorable as in the Bougainville campaign. Hence, the care of the wounded did achieve a very high standard. That this was accomplished is evidenced by the foregoing description of the treatment of all those who were wounded in action and died later.

The first aid treatment was prompt and efficient. Great credit should be given to the aidmen who fearlessly exposed themselves, and high approbation should be accorded to the many who were killed in order that their comrades might live. Plasma was given promptly and in large quantities. Hemorrhage was efficiently controlled in all patients, with only two exceptions. Both of these patients bled to death from traumatic amputations of the foot. Bleeding had ceased while the patient was at rest but began anew during transportation (fig. 184). These patients might have been saved by the use of a tourniquet. Considerable criticism was heard because sucking wounds of the chest were not tightly sealed by the adequate use of adhesive. However, no patient was known to have died for this reason.

The division medical services were adequately staffed to care for the type of surgery they were expected to do. Most of the major surgery was done

U.S. Army photo

FIGURE 184.—Litter carry. Long and difficult litter carries contributed to some deaths.



U.S. Army photo

FIGURE 185.—A screened operating room in a clearing station. Note excellent sterile technique.

at the 21st Evacuation Hospital, because of its proximity to the front. The clearing stations and portable surgical hospitals were usually bypassed in order to save time in the case of the seriously wounded. Minor surgery was done in the clearing stations (fig. 185). One clearing station sutured approximately 50 superficial wounds and obtained primary healing in all. This was done as a trial, and no untoward results ensued as the procedure was limited strictly to superficial flesh wounds. Though two portable surgical hospitals were available, they were not necessary in the Bougainville campaign. A few patients who underwent operation at these hospitals were transferred immediately or shortly after operation before recovering from shock. This factor may have contributed to a fatal termination in some instances. Rapid evacuation of patients (fig. 186) to the hospitals was possible, because of excellent roads and the short distance from perimeter to hospital. More than 80 percent of all patients reached the hospital within 3 hours.

The 21st Evacuation Hospital was staffed with well-qualified specialists, and no patient here failed to achieve adequate specialized care. The value of a neurosurgeon at the front is frequently a disputed point. In island warfare, unless a competent surgeon is assigned locally, the patient may have to be evacuated for a distance of hundreds of miles. Hence, the various specialists should be available, if possible, on the island where combat occurs. Especially is the thoracic surgeon of great value at the front, if the lives of patients needing his services are to be saved. The chief deficiency in the ranks

U.S. Army photo

FIGURE 186.—Jeep ambulance. The jeep ambulance carrying three litters was well adapted for use over jungle trails.

of the specialists is the lack of adequately qualified anesthetists. One such anesthetist was available at the 21st Evacuation Hospital, but, when faced with the problem of anesthetizing eight patients simultaneously, his problem was insurmountable. As is the case so frequently, it was impossible to determine which deaths to attribute to improper anesthesia. Good anesthesia is of first importance in dealing with wounds which require major surgical procedures in the presence of impending shock.

Plasma was used in large quantities in the hospitals as well as in the forward areas. Blood transfusions were more liberally used in this campaign than in any other in the South Pacific. Over 400 transfusions were given in the 21st Evacuation Hospital, with only three reactions. Blood loss was usually great, and very large quantities of blood were required to restore blood volume. Blood counts and hemoglobin determinations revealed these huge blood deficits, and further confirmation was frequently obtained at post mortem. All blood was donated by troops on the island and furnished from a blood bank maintained at the hospital.

Professional care of the wounded was excellent and even the unavoidable errors of judgment incident to war surgery were at a minimum. There were four patients who died of gas gangrene infections, but only one death could be attributed to an error of surgical judgment. In this instance, closure of the wound by suture was probably responsible. There were no deaths due directly to compound fractures of the extremities. Only three patients died

in the rear echelon. The total mortality among 2,015 treated wounded was 3.7 percent. The total mortality among 1,788 treated in hospitals was 5.1 percent. The total operative mortality was 3.5 percent.

MORBID ANATOMY

The study of morbid anatomy in battle casualties is limited by the facilities[15] and the personnel available as well as the circumstances of battle. In the tropics, it is still further limited by the number of dead which must be studied before decomposition, which occurs early.

This report includes 395 dead on which 104 post mortem examinations were performed. Explanation for the relatively small number of autopsies is twofold. First, the assigned pathologist was on detached service at Bougainville for less than one-half of the period covered in this study. Second, many deaths occurred on patrol or in areas which remained under enemy fire, and the bodies were not recovered until decomposition had ensued and consequently examinations were omitted.

All autopsies were performed at Bougainville except in three instances in which death occurred in hospitals in the rear echelon. Allied dead numbered 99 of which 19 were Fijian Scouts and their New Zealand officers. Five Japanese bodies were examined to make the total of 104.

The completeness of the post mortem examinations was determined by the circumstances, such as the condition of the body, whether the cause of death was obvious, and the number of bodies awaiting autopsy (largest number was 26 on one afternoon). Every effort was made to determine the cause of death and to record the gross effects of the missile, its wounds of entrance and exit, and its effects on tissues and organs.

The wounds of entrance responsible for death are shown in figure 187. In the case of multiple wounds, whenever it was possible to decide which of two or more were responsible for death, the wound which caused instantaneous death was recorded. Missiles entering the body in the lateral plane are indicated at the extreme edge of the profile diagram.

Although the number of wounds is small, these figures may give some indication of the number of lives which might possibly be saved by protective armor. A proposed armor chest plate (9″ x 8″) covered a square outlined by the sternal notch above, the xiphoid process below, and the nipples laterally. Such a plate could possibly have prevented perforations of the chest cavity in

[15] Facilities for post mortem examination were courteously provided by the 21st Evacuation Hospital. The morgue, a screened storage tent with a concrete floor, running water, and electric lights, exceeded expectations for a combat zone. The tent was surrounded by a 6-foot canvas wall which helped to isolate it from the hospital wards. Vehicles could reach the area without driving past the ward installations. Technicians to assist with the work were detailed by the 21st Evacuation Hospital and the 52d Field Hospital. A stenographer and photographer recorded all significant wounds and photographed all recovered missiles, fragments, or foreign bodies. When identification of fragments was difficult, they were taken to the Ordnance Section of the XIV Corps for expert opinion. The Cemetery and Graves Registration Office was conveniently located near the hospital, and all dead as they were received at the cemetery were transferred to the morgue for examination.

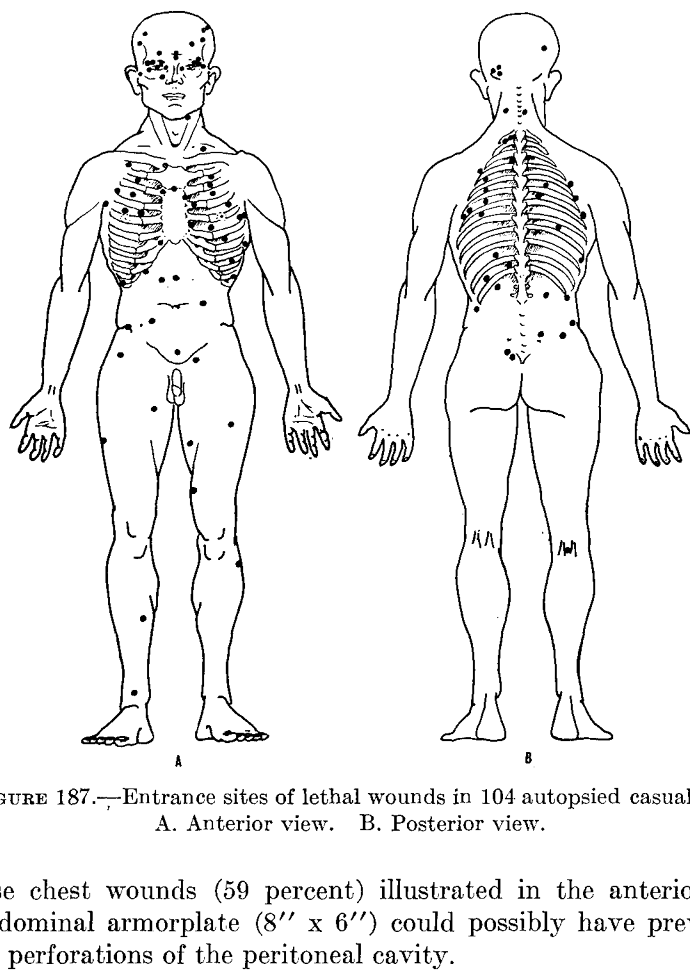


FIGURE 187.—Entrance sites of lethal wounds in 104 autopsied casualties. A. Anterior view. B. Posterior view.

16 of these chest wounds (59 percent) illustrated in the anterior view. A central abdominal armorplate (8″ x 6″) could possibly have prevented 4 of the 7 fatal perforations of the peritoneal cavity.

Morbid Anatomy of Wounds by Region

The autopsied dead were classified under anatomic regions (table 94) according to the location of the wound considered responsible for death. In many instances, multiple wounds were present. For this reason, it was necessary to reserve the classification "Multiple Wounds" for those cases in which two or more wounds could have been responsible for death. There were 104 post mortem examinations; 68 of these dead were killed instantly, and 36 were wounded, treated, and died later.

Head.—In this study, 26 (25 percent) of the autopsied dead sustained fatal head wounds; 20 of these were killed instantly, and 6 were wounded and died later. Characteristic of this group was the extent and magnitude of the fragmentation of the skull found at autopsy. Extensive comminution of the vault with radiating basal fracture lines was almost invariably present in these

compound fractures. Indriven bone splinters were common. The accompanying severe laceration, herniation, or avulsion of the brain was obviously the cause of death in all head cases. None of the four patients on whom operation was undertaken survived longer than 48 hours. In three of these, an apparently hopeless prognosis existed from the time of injury.

TABLE 94.—*Distribution of fatal wounds in 104 autopsies, by anatomic location*

Anatomic location	Total dead		Killed instantly		Wounded-treated-died-later	
	Number	Percent	Number	Percent	Number	Percent
Head	26	25. 0	20	76. 9	6	23. 1
Thorax	32	30. 8	23	71. 9	9	28. 1
Thoracoabdominal	16	15. 4	9	56. 3	7	43. 7
Abdomen	12	11. 5	6	50. 0	6	50. 0
Lower extremity	10	9. 6	4	40. 0	6	60. 0
Multiple wounds	8	7. 7	6	75. 0	2	25. 0
Total	104	100. 0	68	65. 4	36	34. 6

Thorax.—There were 32 (30.8 percent) deaths from thoracic wounds, and of this number 23 died instantly and 9 died later. Almost half (46.2 percent) of all deaths resulted from a combination of thoracic and thoracoabdominal wounds. Remarkable to note was the widespread destruction produced by high-velocity bullets. Gross damage or "blast effect" [16] in the opposite lung by such missiles was clearly demonstrated in six instances and later confirmed by microscopic sections. In two such cases, death was attributed to cardiac failure, and in these right ventricular dilatation was found. It was suggested that the pulmonary injury may have produced a partial obstruction of the pulmonary circulation. The rapid administration of intravenous fluids may have contributed to the cardiac dilatation.

Laceration of the lung by perforating or penetrating missiles was present in all cases. The left lung was involved in 15 cases, the right in 9, and in 8 instances bilateral lesions were present. Injury to the lung alone resulting in massive unilateral hemothorax caused death in 13 cases. It was not uncommon to find from 3 to 4 liters of blood in the pleural cavity. Of the 13 patients, 7 survived to undergo operation; the others died instantly. The size of the various external chest wall wounds bore no relation to the amount of underlying damage. Particularly striking were the small external wounds of the high-velocity bullet which were so frequently accompanied by extensive laceration

[16] Damage resulting from formation of temporary cavity and not related to the pulmonary hemorrhage seen in air blast injuries. The latter is due to the destructive force of the pressure wave set up by the detonation of high explosives. Any pulmonary (or visceral) damage resulting from the passage of a high-velocity missile is dependent upon the formation of a temporary cavity. Blast injuries are seen in association with aerial bombardment and detonation of high explosives, such as dynamite, bangalore torpedoes, and landmines. See also footnote 14, p. 352.—J. C. B.

and destruction of intrathoracic structures. The lower velocity fragments of explosive shells and bombs as a rule produced more extensive external defects. Bone fragments derived from ribs were common along the wound track. With the exception of Case 36, in which a metal button was removed, no foreign material was recovered.

In order of frequency, perforation or laceration of the intrathoracic structures occurred as follows: Heart, 8; aorta, 5; pulmonary artery, 4; and trachea and esophagus, 2. The thoracic cord was transected in 3 cases and the cervical cord in 1. Wounds of the heart and great vessels were found in approximately 50 percent of these cases. Hemorrhage was the cause of death in 85 percent of thorax wounds.

Thoracoabdominal wounds.—Multiple lesions of the abdominal and thoracic cavities in the same individual accounted for 16 (15.4 percent) deaths. Only those cases in which one missile was responsible for the combined injury are included in this group. The wound of entry was through the thoracic wall in 12 of the 16 cases. Nine were killed instantly, and the remaining seven underwent operation and died later. Four patients had thoracotomy, two laparotomy, and one had both laparotomy and thoracotomy. Five of these patients died within 24 hours from hemorrhage and shock, one after 8 days from secondary hemorrhage, and one (Case 68) after 6 days from cardiorespiratory failure.

The cause of death in 15 of the 16 cases was hemorrhage and shock, hemothorax and hemoperitoneum being frequently combined. The lung was injured in all cases, the heart perforated in one, the thoracic aorta in one, and the abdominal aorta in another. The abdominal organs injured in order of frequency were liver, spleen, hollow viscus, kidney, and pancreas.

Abdomen.—There were 12 (11.5 percent) fatal abdominal wounds. In 5 of the 6 patients who died instantly, death resulted from hemorrhage, and, in the sixth patient, it was due to shock from evisceration. Of the six patients who had laparotomy, none lived longer than 4 days following operation. In these cases, 1 death was attributed to hemorrhage, 1 to paralytic ileus and uremia (Case 84), and 4 to peritonitis.

Multiple lesions were usually present. In order of frequency, the abdominal organs injured were as follows: Jejunum, ileum, transverse colon, and rectum, 11; major vessels, 5; kidneys, 4; liver, 2; pancreas, 2; and spleen, 1. Fractures of the vertebral bodies were found in four instances. Damage to the spinal cord occurred in one case and to the cauda equina in another.

Lower extremities.—Wounds of the lower extremities were responsible for 10 (9.6 percent) deaths. Hemorrhage from the femoral artery accounted for death in four of the soldiers who died instantly. In the other casualties, both Japanese and about whom little is known, death apparently resulted from shock associated with severe compound fractures of the femur. Six patients were wounded and died later; four of this group underwent operation. Gas gangrene accounted for death in 3 (2 Japanese and 1 American) patients; hemorrhage, in 2; and uremia, in one.

Multiple wounds.—Under this heading are classified those cases in which two or more wounds could have been the cause of death. Of the 8 casualties so classified, 5 died instantly with wound distribution as follows: Head and abdomen, 2; head, thorax, and abdomen, 1; thorax and multiple fractures of the femur and extensive multiple wounds, 1; and head with multiple fractures of the femur and tibia and fibula, 1. In all cases, the immediate cause of death was hemorrhage, extensive brain damage, or shock, or a combination of these three.

Two of the remaining patients had undergone operative procedures. One who sustained a traumatic amputation of the leg and multiple wounds and fractures died from shock within 10 hours. The second patient died from gas gangrene after 48 hours following fracture of the femur and other extensive wounds.

Causes of death.—Table 95 lists the various causes of death as determined by post mortem examination among the 104 casualties. Hemorrhage was the most common cause (54.8 percent), and this was followed by brain and spinal cord damage (26 percent). The remaining cases died from a number of other conditions. The following general conclusions were reached as a result of the autopsy study:

1. Hemorrhage, frequently occult, was the most common cause of death.
2. Extensive brain damage was the second most common cause of death.
3. It was impossible to determine with accuracy the causative missile from the appearance of a wound.
4. The extent of the underlying structural damage bears no constant relationship to the size of the wound of entrance or exit. This fact is frequently not appreciated by the young, inexperienced battle surgeon and is of great significance in the proper care of the patient.

TABLE 95.—*Cause of death in 104 casualties as determined by post mortem examination*

Cause	Dead	
	Number	Percent
Hemorrhage	57	54. 8
Brain or spinal cord damage	27	26. 0
Shock not due to hemorrhage	5	4. 9
Peritonitis	4	3. 9
Gas gangrene	4	3. 9
Cardiac failure	2	1. 9
Uremia	2	1. 9
Pulmonary edema	1	. 9
Pulmonary embolus	1	. 9
Empyema with sepsis	1	. 9
Total	104	100. 0

5. Foreign material, except for the wounding missile, was seldom found.

6. Contralateral brain and lung damage from high-velocity missiles was a frequent finding. Temporary cavity effect on the contralateral lung may result in sequelae further impairing the pulmonary circulation.

7. High-velocity missiles striking large blood vessels or solid organs usually produced an explosive effect rather than a perforation.

Morbid Anatomy of Wounds by Weapon

Table 96 lists the types of weapons responsible for the lethal wounds in the autopsied cases.

Wounds caused by rifle.—The rifle was the weapon responsible for death in slightly less than half (42.3 percent) of the autopsied cases. Table 97 shows the anatomic distribution of wounds among those killed by rifle fire.

Head.—Head wounds produced by rifle fire were characterized without exception by extensive destruction of the brain and skull. Laceration, massive herniation, or total absence of large portions of the brain were the usual findings. Large areas of bony skull and scalp were frequently avulsed with shattering or widespread comminution of the residual portions of the skull. Ofttimes, bone fragments were driven deep into the brain tissue. Perforating skull wounds were more common than gutter wounds. Frequently, long, stellate fracture lines radiated across the base of the skull. Extensive damage was sometimes observed in one hemisphere of the brain, when the traversing missile track lay entirely in the opposite hemisphere. All these findings were interpreted as additional evidence in support of the modern hypotheses [17] of wound production by high-velocity missiles.

TABLE 96.—*Weapons causing wounds in 104 casualties, as determined by post mortem examination*

Weapon	Total casualties		Killed instantly		Wounded-treated-died-later	
	Number	Percent	Number	Percent	Number	Percent
Rifle	44	42. 3	31	70. 5	13	29. 5
Mortar	24	23. 1	13	54. 0	11	46. 0
Machinegun	13	12. 5	8	61. 5	5	38. 5
Grenade	7	6. 7	4	57. 1	3	42. 9
Mine	7	6. 7	5	71. 4	2	28. 6
Artillery	6	5. 8	5	83. 3	1	16. 7
Miscellaneous	3	2. 9	2	66. 7	1	33. 3
Total	104	100. 0	68	65. 4	36	34. 6

[17] The observation that a high-velocity bullet produces terrific destruction of tissue at a considerable distance from its permanent wound track is well established. See chapter III, p. 144.

TABLE 97.—*Anatomic distribution of wounds among 44 casualties killed by rifle fire, and weapon from country of origin*

Anatomic location	Casualties			Weapon	
	Killed instantly	Wounded-treated-died-later	Total	Japanese	United States
	Number	*Number*	*Number*	*Number*	*Number*
Head	12	3	15	13	2
Abdomen-thorax	1	3	4	4	0
Thorax	12	5	17	15	2
Abdomen	2	1	3	3	0
Lower extremities	3		3	1	2
Multiple	1	1	2	2	0
Total	31	13	44	38	6

There were no features present to distinguish the wounds produced by the Japanese rifle from those produced by the U.S. rifle nor were there any dissimilar findings in the wounds of those killed instantly and those who were wounded and died later. Perforating wounds completely traversing the skull were recorded frequently by the Japanese .25 caliber bullet at varying distances from 10 feet to 150 yards.

Perforation of the U.S. helmet by enemy rifle fire was found in six instances. The maximum recorded distance at which this occurred was 100 yards. A sample of the sizes of the entrance and exit wounds, respectively, of the head produced by the Japanese rifle at various distances follows: At 150 yards, 0.6 and 1.2 cm.; at 100 yards, 2.5 and 3 cm.; at 20 yards, 0.5 and 1.2 cm.; and at 15 yards, 3.7 and 8.7 centimeters.

Thorax.—All rifle wounds of the chest were with two exceptions complete perforating wounds. In both these instances, the enemy .25 caliber bullet failed to perforate the thorax at a distance of 25 yards.

Massive intrathoracic hemorrhage was the immediate cause of death in all those killed instantly and in two patients who were wounded and died a few hours later. Transection of the spinal cord with fracture of vertebra was present in four instances. In two of these, death occurred immediately, and in both cases massive hemothorax was found. In one of the other two cases, death occurred in 24 hours associated with terminal hyperthermia and in the other after 1 month following an extensive empyema complicated by a bronchopleural fistula.

Fairly typical of the extensive thoracic damage caused by the .25 caliber Japanese rifle bullet is Case 40. This soldier was struck in the chest at moderately close range. The entrance wound was situated in the seventh posterior intercostal space, and the exit wound was over the clavicle. All ribs from fourth to eighth, inclusive, were fractured in addition to the clavicle.

The upper and lower lobes were severely lacerated, and a massive hemothorax was present.

Table 98 lists the sizes of known wounds of entrance and exit at various ranges.

TABLE 98.—*Size of wounds of entrance and exit, caused by rifle bullet, at various ranges*

Distance of range	Wound of—	
	Entrance	Exit
Yards	*Cm.*	*Cm.*
−1	0.6	2.5
5	.5	1.2
5	1.8	3.8
20	.5	3.7
20	3 x 1	3.8 x 2.5
25	.5	1.5 x 1
30	.6	4.3
30	.6	2.5
30	.5	2.5
35	.5	

Thorax and abdomen.—The force of the .25 caliber Japanese rifle bullet when fired at moderately close range (25 yards or less) was well demonstrated by the great number of structures and organs injured when the thorax and abdomen were traversed by the same missile. Structures perforated in each of four illustrative cases are listed here: Case 67—anterior chest wall, upper lobe of left lung, left ventricle, right ventricle, lower lobe of right lung, diaphragm, liver, lateral chest wall; Case 71—abdominal wall, jejunum, ileum, transverse colon, liver, diaphragm, lower lobe of right lung, chest wall; Case 68—chest wall, lung, diaphragm, colon, spleen, kidney; Case 69—left elbow (fracture of humerus), chest wall, both lobes of left lung, diaphragm, spleen, kidney, chest wall. The latter patient lived 8 days and died of secondary hemorrhage from lung and spleen. Death in the third case occurred on the following day and resulted from cardiorespiratory failure. In the first two cases, massive hemothorax and hemoperitoneum were present at autopsy.

Abdomen.—The powerful disruptive effect of the rifle bullet on various abdominal structures can be appreciated best by enumerating its destructive effects in the individual case. Three patients were struck in the abdomen by Japanese rifle bullets at distances of 20 yards, 75 yards, and at an unknown distance. Respectively, their important injuries were: Case 77—fracture of the ilium and sacrum, perforation of the rectum, and massive hemoperitoneum; Case 78—fracture of the rib and vertebra, extensive lacerations of the liver, kidney, and transverse colon, and hemoperitoneum; and Case 81—extensive lacerations of the kidney and liver with hemoperitoneum. Common to all these cases and characteristic in the wounds of the solid organs in the kidney,

liver, and spleen was the widespread "shattering" and fragmentation produced by the explosive effect of the missile in its passage.

Lower extremity.—A Fijian soldier (Case 87) was struck in the groin by an enemy rifle bullet which severed the femoral artery and vein. He died within a few minutes from exsanguination. A Japanese soldier (Case 89) sustained a severe compound comminuted fracture of the middle third of the femur and died from shock several hours later despite therapy. Cursory examination of the decomposed body of another Japanese soldier (Case 90) revealed an extensive compound comminuted fracture of the femur with a very large wound of exit (16.6 x 13.9 cm.) but with intact femoral vessels. In these last two cases, death apparently resulted from severe shock without significant concomitant hemorrhage.

Multiple.—Two patients sustained multiple rifle wounds. One of these (Case 101) died instantly, the other (Case 103) died 2 days later from peritonitis and gas gangrene.

Mortars and grenade discharges.—Mortar fire accounted for death in approximately one-fourth (23.1 percent) of the autopsied cases. The anatomic distribution of wounds among those killed by this weapon is shown in table 99.

TABLE 99.—*Anatomic distribution of wounds among 24 casualties killed by mortar fire, and weapon from country of origin*

Anatomic region	Casualties			Weapon	
	Killed instantly	Wounded-treated-died-later	Total	Japanese	United States
Head	4	2	6	3	3
Abdomen-thorax	2	2	4	4	0
Thorax	5	1	6	4	2
Abdomen	1	2	3	2	1
Lower extremity	0	4	4	2	2
Multiple	1	0	1	1	0
Total	13	11	24	16	8

It is interesting to observe that the immediate lethal effect of the low-velocity mortar fragment is appreciably less than that of the high-velocity rifle bullet. Only slightly more than half of the autopsied dead, wounded by the mortar, died instantly; whereas, over two-thirds of all autopsied cases struck by rifle bullets were killed instantly.

Head.—In cases in which perforation of the skull occurred, the size of the skull wounds and distance from the burst was known in three. At 25 yards, a fragment (3 x 1 x 0.8 cm.) of a U. S. 90 mm. shell perforated the skull and resulted in death 2 hours later from the extensive brain damage (Case 12).

The entrance wound in this case measured 2.5 cm. in diameter. A U.S. 90 mm. shell exploding at a distance of 20 yards produced a large gutter wound in the skull measuring 6.2 x 1.8 cm. (Case 3). Death followed in 3 hours. A small metal fragment (20 x 4 x 4 mm.) was recovered from the inner table of the skull. In the third instance (Case 26), a soldier was struck by a fragment from a Japanese 90 mm. shell at a distance of 7 yards. An entrance wound of 2.5 x 0.5 cm. was produced. This soldier expired after 12 hours from the cerebral injury.

Thorax.—A fairly characteristic feature of mortar wounds of the thorax was the extraordinary extent of the defect identified as the wound of entrance. For example, a Fijian soldier (Case 29) was killed instantly by a fragment from a U.S. 90 mm. shell which burst 20 yards away. Even from that distance, the fragment completely traversed the thorax and produced a wound of entrance 8.2 x 6.8 cm. and a wound of exit 20 x 12.5 cm. In another instance (Case 46), an entrance wound defect over the region of the scapula measuring 20 x 10 cm. was produced by a fragment of a 90 mm. Japanese mortar shell bursting at a distance of 20 yards. On the other hand, a mortar fragment in its greatest dimension measuring a little more than 1.0 cm. caused death from intrathoracic hemorrhage (Case 48). This fragment originated from an enemy 90 mm. shellburst at 10 yards. The wound of entrance in this case measured only 1.5 cm. One patient (Case 51) survived for a period of 3 days following severe chest injuries resulting from the explosion of a U.S. 4.2-inch mortar shell at a distance of 3 yards.

Abdomen.—In the abdomen, extensive laceration of multiple organs and structures was frequently observed. Death in these, if immediate, resulted from hemorrhage and shock. Two patients surviving for 3 and 5 days, respectively, after laparotomy, died of peritonitis. The first patient (Case 83) was struck in the abdomen by a fragment of an enemy 90 mm. mortar shell at a distance of 25 yards. Multiple perforations of the jejunum and colon resulted, but unfortunately the jejunal lacerations were overlooked at operation. The second patient (Case 84) was wounded by the burst of a 4.2-inch U.S. mortar shell at a distance of 3 yards. The largest external defect in this case was an entrance wound measuring 10 x 5 cm. over the region of the right iliac crest. Laceration of the right kidney and cauda equina and a large retroperitoneal hematoma were found at operation.

Lower extremity.—There were four autopsied dead who had sustained lower extremity wounds only. One of these deaths might have been prevented. In this case, a soldier's foot was blown off by the pointblank burst of an enemy shell (Case 91). Evacuation of this patient was effected at night, 24 hours later. In the process of transportation by litter, and unknown to the aidmen, delayed hemorrhage occurred and the soldier expired. In another case (Case 93), amputation was performed 1 day after injury, because of damaged blood supply to the extremity. This patient died 5 days later with uremia, the cause of which was unknown. A U.S. 81 mm. "short" exploded between the legs

of a soldier (Case 94) who lived thereafter for 6 hours. Traumatic amputations of both lower extremities resulted, the left thigh and right leg at the level of their upper thirds. A Japanese soldier (Case 96) died of gas gangrene 4 days after being wounded. The femoral vessels were intact but thrombosed, and the femur was not fractured. In this instance, the wound on the medial surface of the thigh measured 17 x 16.2 centimeters.

Two small external wounds resulted from the explosion of a 90 mm. Japanese mortar shell at a distance of 2 yards in a patient (Case 99) who survived only a few hours. One wound over the parietal region measuring only 1.5 cm. in diameter had resulted in extensive intracranial injury and hemorrhage. The liver and right kidney were extensively lacerated, and a massive hemoperitoneum was present. This was the only case listed under "Multiple Wounds" by mortar fire.

Machinegun.—The only distinguishing feature between rifle and machinegun wounds is that the latter are more often multiple. In all other respects, wounds produced by rifle and machinegun bullets of like caliber and muzzle velocity are identical. There were 26 separate wounds in these 13 dead. Grouped anatomically, the wounds responsible for death were divided as follows: Head, 2; thorax, 4; thorax-abdomen, 5; and abdomen, 2. Eleven were killed by enemy weapons and two by U.S. weapons. Eight of the thirteen autopsied were killed instantly; with one exception, the remaining wounded died within a few hours. Two of the dead were struck by .25 caliber bullets at distances of 150 yards, this being the maximum range recorded. In one of these (Case 27), a perforation of the thorax resulted, the entrance wound of which measured 2 cm. and the exit wound 3 x 1.5 cm. In the other (Case 5), a larger gutter wound of the skull was found, measuring 6.5 x 2.5 centimeters.

Grenades.—The grenade produced death in seven (6.1 percent) of the autopsied cases. Four of these deaths resulted from the U.S. grenade and three from the Japanese. The anatomic distribution of fatal wounds among the autopsied dead was: Abdomen and thorax, 2; thorax, 1; abdomen, 2; lower extremity, 1; and multiple, 1. With one exception, all patients wounded by grenades had multiple wounds. This soldier (Case 92) while on guard tripped the wire of a U.S. grenade boobytrap and was struck in the buttock by a single fragment. He died 6 days later from gas gangrene. A U.S. grenade exploded in the hand of an American soldier (Case 85) returning from patrol. Multiple abdominal organs and intestinal loops were perforated. Despite laparotomy and supportive treatment, this patient died on the following day. Multiple wounds and massive intrathoracic hemorrhage were found in two soldiers whose deaths resulted from pointblank bursts of U.S. grenades. In one instance (Case 98), a soldier returning to his own foxhole was mistaken for the enemy, and in the other (Case 64) an unexplained explosion occurred in the pocket of a soldier returning from patrol. Three deaths resulted from pointblank explosions of Japanese hand grenades, and in all instances multiple wounding was present. The cause of death was intrathoracic hemorrhage in

the two cases in which death was instantaneous. In the other case, the patient died after 12 days from generalized suppurative peritonitis due to evisceration following laparotomy. The grenade fragments did not perforate the abdominal cavity. No conclusions can be drawn from these dead as to different effects of the Japanese and U.S. grenades.

Artillery.—Of the six autopsied dead resulting from artillery fire, four were killed instantly by U.S. weapons. Two of these dead (Cases 9 and 16) sustained severe head wounds from 75 mm. shellbursts at distances of 5 and 12 yards, respectively. In the other two cases, death resulted from extensive thoracic wounds, produced in one (Case 34) by a U.S. 37 mm. shellburst at 3 yards and in the other (Case 42) by a U.S. shell of unknown caliber at a distance of 5 yards. One patient (Case 13) was killed instantly and another (Case 57) lived for only a few hours following the explosion of a Japanese shell (probably 150 mm.) at distances of less than 2 yards.

Landmines.—That the U.S. landmine is a most deadly weapon is convincingly demonstrated by the autopsy findings in seven cases. Each of these dead had multiple wounds, and all except two were killed instantly. One of the two who survived the initial blast was a Japanese soldier (Case 95). His death later in an American hospital was due to gas gangrene. The other was an American soldier (Case 104) who lived a little more than 6 hours and died from shock. The post mortem findings in this instance well illustrate the multiplicity of wounds found. The soldier sustained a traumatic amputation of the foot and 13 penetrating wounds. Present also were compound comminuted fractures of the patella, internal malleolus of the tibia, sacrum, and ulna.

Other examples of the extreme degree of trauma caused by these landmines as seen are the cases of five soldiers who were killed instantly. A striking illustration is that of a soldier (Case 102) in whom avulsion of the right and left frontal lobes and part of the right parietal lobe occurred with destruction of the orbit, frontal bone, and an area of skull measuring 10 x 6 cm. In addition, compound fractures of the tibia (bilateral), fibula, femur, ulna, and mandible were present. Altogether, there were 18 widely distributed perforating and penetrating wounds. One other case will suffice to illustrate the lethal effect of this weapon. Post mortem examination showed seven penetrating and perforating wounds (Case 100). A fragment passed through the skull, fracturing the maxilla, zygoma, and temporal bones, and then made its exit through the frontotemporal region. In its course, the missile destroyed the right frontal lobe. Another fragment entered the abdomen, severed or perforated the pylorus, duodenum, jejunum, and small intestine mesentery, and finally lodged in the bifurcation of the aorta. The peritoneal cavity was filled with blood, the brachial plexus was severed, and there were numerous other wounds of the thoracic and abdominal walls and thigh.

In all these instances, it is assumed that the victim either stepped directly on the mine or was injured at close range by having tripped a mine wire.

AUTOPSY PROTOCOLS

Case 1.—A soldier of the 164th Infantry, while walking through thick jungle toward Allied lines returning from patrol, was mistaken for the enemy and shot through the head with an M1 rifle at a distance of 30 yards by a fellow soldier. He was wearing a helmet when struck and this was perforated in the front and back. He was killed instantly at 1700 hours on 1 April 1944.

Examination revealed a perforating wound of the skull. The bullet produced a wound of entrance (3 cm. in diameter) through the left orbit and a wound of exit (2.5 cm. in diameter) at the junction of the parietal and occipital bones. Comminution of the cranial vault with diffuse disruption of the brain was present (fig. 188).

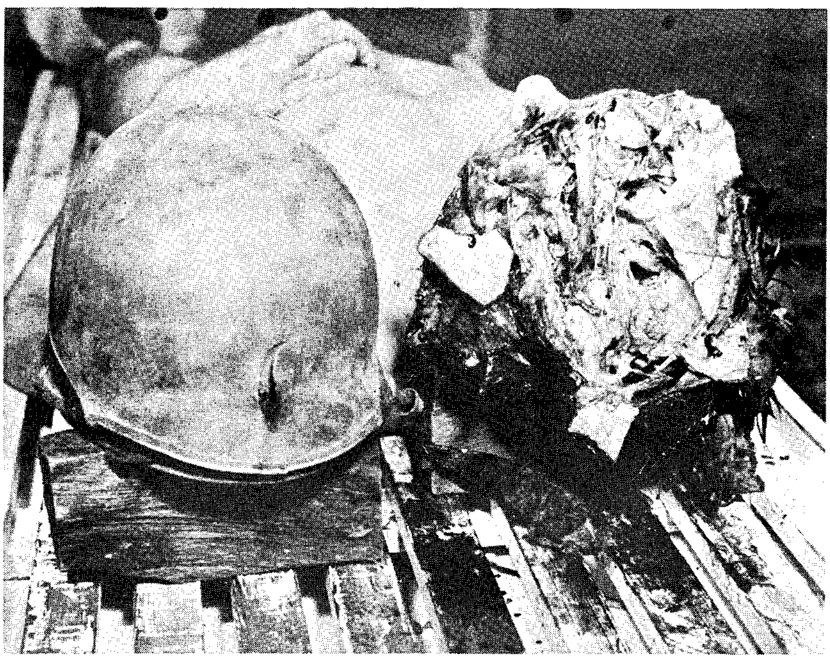


FIGURE 188.—Widespread destruction of cranial vault and brain (scalp retracted).

Case 2.—A Fijian soldier, while on patrol, was standing behind a tree when he was struck by a .25 caliber Japanese bullet fired from a distance of 20 yards. He was killed instantly on 31 March 1944.

Examination revealed a perforating wound of the head. The entrance wound (0.5 cm. in diameter) was situated over the lateral border of the right supraorbital ridge and the exit wound (1.2 cm. in diameter) over the occipital bone. Stellate fractures of the frontal and occipital bones radiated from both perforations. The frontal and parietal lobes of the brain were perforated, and the cerebellum was grooved.

Case 3.—A Fijian soldier, while on patrol, was standing digging a foxhole when he was struck by a fragment from a U.S. 90 mm. shell. The shell exploded on the ground at a 20-yard distance. He was wounded at 1700 hours on 30 March 1944 and died 3 hours later in the hospital. Death was attributed to severe brain damage.

Examination revealed a gutter wound (6.2 x 1.8 cm.) in the right frontal region. A stellate fracture involved the vault of the skull (fig. 189). The fragment coursed obliquely

FIGURE 189.—Extensive fracture of skull at site of entrance wound.

through the right cerebral hemisphere to the posterior aspect of the left parietal lobe. A metallic fragment (20 x 4 x 4 mm.) was recovered at this point and was found to be partially imbedded in the inner table of the skull.

Case 4.—A soldier of the 129th Infantry, crouching behind a tree stump, stood to throw a hand grenade and was struck in the head by a .25 caliber Japanese bullet fired from a distance of 10 feet; he was wearing a helmet which was perforated on the left side. He was killed instantly at 0930 hours on 24 March 1944.

Cursory examination [18] revealed a perforating wound of the left side of the skull. The entrance wound involved the left orbit. The exit wound was found over the left parieto-occipital region. Brain tissue exuded from both openings. The cranial vault was severely comminuted and the left cerebral hemisphere destroyed.

Case 5.—A Fijian soldier, while on patrol, peered over a ridge and was struck in the head by a .25 caliber Japanese machinegun bullet fired from a distance of 150 yards. He was killed instantly at 1000 hours on 26 March 1944. After death from the head wound, he was struck again in the chest by a fragment from an artillery shell.

Examination revealed a gutter wound (6.5 x 2.5 cm.) in the center of the forehead with a portion of the frontal bone blown away. Fracture lines radiated through the temporal, parietal, and occipital bones. Both frontals and the right temporal lobes were lacerated. A bullet was recovered from the right temporal fossa. The chest was penetrated by a shell fragment entering through a wound (10 x 5.6 cm.) in the left seventh and eighth intercostal spaces in the anterior axillary line. In its course, the fragment fractured the 8th, 9th, 10th, and 11th ribs, lacerated the lower lobe of the left lung, the upper and lower lobes of the right lung, fractured and perforated the bodies of the seventh and eighth dorsal vertebras,

[18] On this afternoon, 26 bodies were received, and, since time did not permit a complete examination of all cases, some of these in which the cause of death was obvious received only cursory examinations.

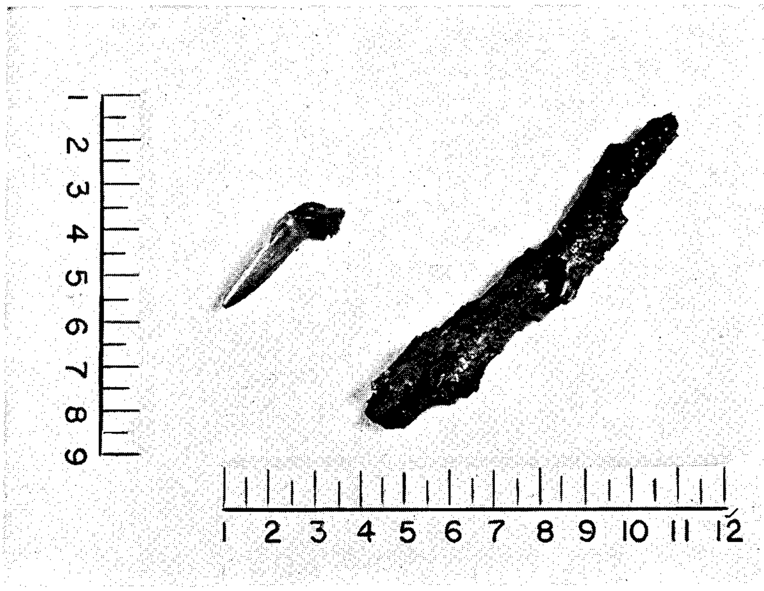


FIGURE 190.—Missile fragment of (left) .25 caliber Japanese machinegun and of (right) artillery shell recovered from head and chest wounds.

transected the spinal cord, and fractured the third, fourth, fifth, and sixth ribs at the costovertebral junctions. The fragment was lodged in the subcutaneous tissue of the right posterior chest wall.

Figure 190 shows the two recovered missiles.

Case 6.—A soldier of the 117th Engineer Combat Battalion, while lying in an open foxhole in a cleared area of the jungle, was struck by fragments of a Japanese mortar shell. The shell exploded on the ground at a distance of 1 yard. He was killed instantly at 2015 hours on 24 March 1944.

Examination revealed a penetrating wound of the head. The entrance wound (2.5 cm. in diameter) perforated the left occipital bone. There was severe comminution of the cranial vault, and several fracture lines continued inferiorly through the base of the skull traversing the foramen ovale and cribiform plate. The left occipital amd temporal lobes were severely lacerated, and small indriven bone fragments were removed from these lobes. Two metal fragments were recovered from the depth of an irregular laceration of the left cerebellar hemisphere. The fragments measured 15 x 5 x 1 mm. and 15 x 10 x 2 mm. Figure 191 shows the extensive skull fractures and the recovered fragments.

Case 7.—A soldier of the 129th Infantry was lying behind a tree root and was struck by a Japanese .25 caliber bullet fired from a distance of 10 yards. He was killed instantly at 1000 hours on 24 March 1944.

Cursory examination revealed a perforating wound of the skull. The entry wound traversed the right orbit, and the exit wound was found over the parieto-occipital region. The cranial vault was extensively fractured, and marked destruction of the right cerebral hemisphere was evident.

Case 8.—A soldier of the 129th Infantry, 37th Division, was standing on his bunk in an open tent in battalion headquarters firing at the enemy, when he was struck by a .25 caliber Japanese bullet fired from a distance of 25 yards. He was killed instantly at 0630 hours on 24 March 1944.

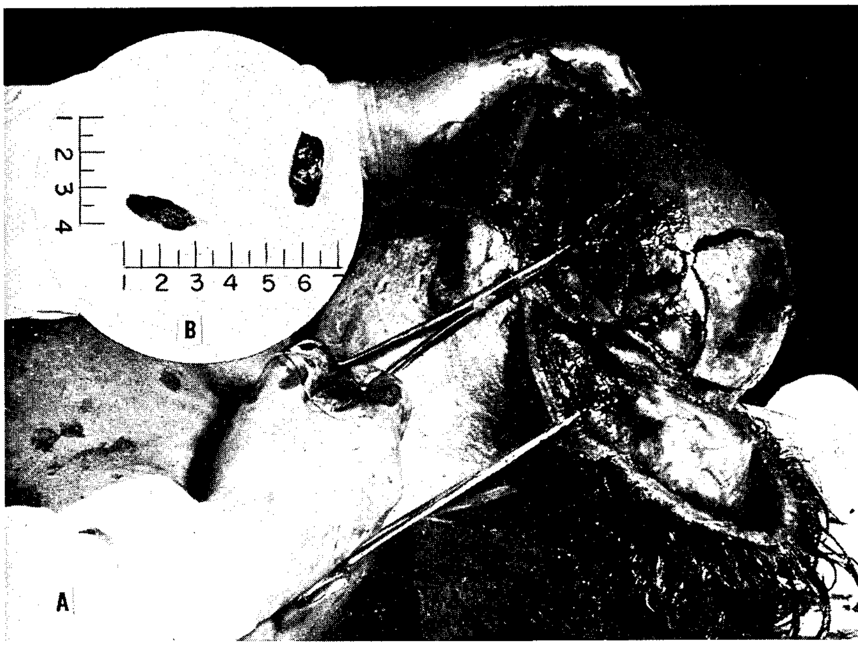


FIGURE 191.—Extensive fracture of skull. A. Site of entrance wound. B. Mortar shell fragments recovered from wound.

Examination revealed a gutter wound (5 x 2½ cm.) of the left parietal region. Brain tissue exuded through the perforation in his helmet. Lacerated brain tissue, portions of the frontal and parietal lobes, was herniated through the wound. Marked subgaleal hemorrhage was present. The cranial vault was comminuted by stellate fractures. Both hemispheres of the brain were extensively lacerated. A mushroomed .25 caliber bullet was found in the right anterior fossa (fig. 192).

Case 9.—A soldier of the 164th Infantry, while on patrol in cleared jungle lying in an open foxhole, was struck by a fragment of U.S. 75 mm. shell which fell short. The shell exploded on the ground at a distance of 5 yards. He was killed instantly at 1600 hours on 26 March 1944.

Examination revealed an extensive gutter wound traversing the left side of the skull. The occipital, parietal, and temporal bones were almost entirely destroyed. Only fragmentary portions of the left cerebral hemisphere remained.

Case 10.—A Fijian soldier, peering over the edge of an open foxhole to fire at the enemy, was struck by a .25 caliber Japanese bullet fired from a distance of 15 yards. He was killed instantly at 1400 hours on 1 April 1944. The body was not recovered immediately and received other wounds from shell fragments after death.

Examination revealed a perforating wound of the head and multiple wounds of the extremities. The head wound of entry (3.7 cm. in diameter) was located at the inner canthus of the left eye and the exit wound (8.7 cm. in diameter) at the vertex of the skull. The skull was comminuted, and there was almost complete destruction of the left half of the brain. Present, in addition, were a perforating wound of the right elbow associated with compound comminuted fracture of the radius, a perforating wound of the soft parts of the right calf, and an extensive gutter wound of the left hand.

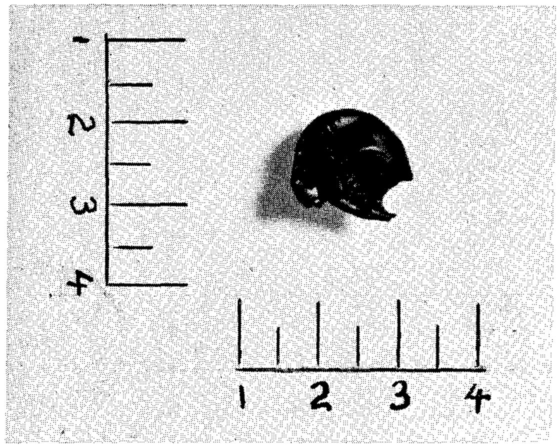


FIGURE 192.—Deformed .25 caliber bullet recovered from right anterior fossa.

Case 11.—A soldier of the 129th Infantry was crouching and moving forward in a skirmish line when he was struck by a Japanese .25 caliber bullet fired from a distance of 20 yards. He was killed instantly at 1300 hours on 24 March 1944.

Cursory examination revealed an extensive gutter wound 15 x 10 cm. involving the left temporal, occipital, and parietal regions. Large portions of these bones and underlying brain were absent. Extensive comminution of the remaining cranial vault was present. Figure 193 shows the destructive effect of the missile.

FIGURE 193.—Head wound.

Case 12.—A Fijian soldier, while on patrol, was standing digging a foxhole when he was struck by a fragment of a U.S. 90 mm. shell. The shell exploded on the ground 25 yards distant. He was wounded at 1700 hours on 30 March 1944 and died 2 hours later. Death was caused by extensive brain damage.

The wound of entry (2.1 cm. in diameter) in the head was located 2 cm. above the right tragus. Brain tissue exuded from this wound. The fragment perforated the temporal bone producing stellate fractures of the temporal and frontal bones. The wound track traversed the right temporal, frontal, and left frontal lobes. A fragment (3 x 1 x 0.8 cm.) was found in the left frontal lobe. Examination revealed additional wounds; traumatic amputation of the left thumb, extensive laceration of the dorsum of the left hand and wrist, and perforating wounds of the soft tissue of the anterior right and left midthighs.

Figure 194 shows a metal probe inserted into the wound of entry in the head and also the extensive hand wound.

FIGURE 194.—Entrance wound in head (with metal probe inserted) and wounds of left upper extremity.

Case 13.—A soldier of the 182d Infantry, while in a covered pillbox on top of a hill, was struck by fragments from a 150 mm. Japanese shell which exploded on the ground 1 yard from the hole. He was killed instantly at 1400 hours on 26 March 1944.

Examination revealed a gutter wound (15 x 5.5 cm.) of the left side of the neck with extensive soft-tissue damage and transection of the external jugular vein. Another gutter wound (10 x 3.7 cm.) extended obliquely across the fifth and sixth cervical vertebras. The vertebras were shattered. At autopsy, the dura was opened and the cervical cord was exposed and found intact. No foreign bodies were found.

Case 14.—A soldier of the 129th Infantry was found dead in the 129th sector on 24 March 1944. He was struck in the left arm and leg by a Japanese .25 caliber bullet. In addition, a head wound was believed to have been caused by a fragment from a Japanese mortar shell.

FIGURE 195.—Head wound.

Cursory examination revealed perforating wounds of the soft parts of the left thigh and arm. A severe penetrating wound through the left orbit was present as illustrated in figure 195. Marked comminution of the cranial vault was found with brain tissue exuding from the head wound.

Case 15.—A soldier of the 132d Infantry was on patrol duty and had bivouaced in the open for the night. During the middle of the night, he stood up to void and was shot by an apprehensive fellow soldier with an M1 rifle at a distance of 10 yards. He was killed instantly at 2550 hours on 21 April 1944.

Examination revealed a perforating wound of the neck. The entrance wound (1.2 cm. in diameter) penetrated the left submental triangle, and the exit wound (12.5 x 7.5 cm.) occupied the posterior cervical region from the third to the sixth vertebras. The fourth and fifth vertebras were shattered; the cord was exposed and was partially severed at the same level.

Case 16.—A soldier of the 164th Infantry, while on patrol in the jungle, was lying on a slope under a tree when he was struck by a fragment of a U.S. 75 mm. shell which fell short. The shell exploded in a tree 12 yards above the soldier. He was killed instantly at 1600 hours on 26 March 1944.

Examination revealed a penetrating wound of the left occipital region 3.7 cm. in diameter. Brain tissue exuded through this wound. The fragment pierced the left occipital bone, left occipital lobe, and left cerebellar hemisphere. A shell fragment was found on the inferior surface of the cerebellum. A linear fracture line extended across the left occipital, parietal, and temporal bones.

The recovered fragment measured 6 x 5 x 4 mm. (fig. 196).

Case 17.—A soldier of the 129th Infantry, while walking up a jungle trail, was struck by a Japanese .25 caliber bullet fired from a distance of 100 yards. He was killed instantly at 1320 hours on 24 March 1944.

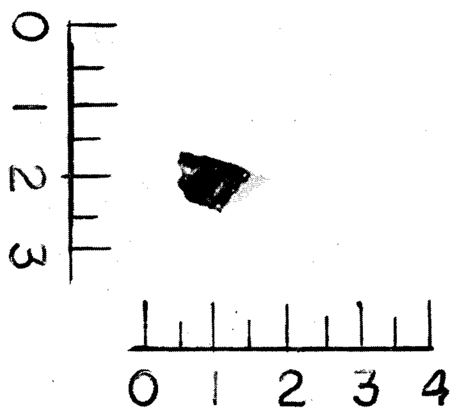


FIGURE 196.—U.S. 75 mm. shell fragment recovered from brain wound.

Examination revealed a perforating wound of the head. The wound of entrance (2.5 cm. in diameter) traversed the right infraorbital ridge; the exit wound (3 cm. in diameter) was located in the left parieto-occipital region. When the body was received, the helmet had not been removed and brain tissue was extruded over its surface.

Case 18.—A U.S. soldier was standing in a cleared area digging a foxhole when he was struck in the head by a .25 caliber bullet. The shot was fired by a Japanese sniper at a distance of over 150 yards. The soldier was killed instantly at 1500 hours on 26 March 1944.

Examination revealed a perforating wound of the head. The entrance wound (0.6 cm. in diameter) was posterior to the left mastoid process, and the exit wound (1.2 cm. in diameter) was at the outer canthus of the right eye. The bullet coursed in a superior and anterior direction and perforated the atlas; it then crossed the foramen magnum and severed the brain stem at the lower level of the pons. The track continued through the base of the skull, right ethmoid, and right orbit to the point of exit. Figure 197 shows a catheter in the wound track.

Case 19.—A U.S. soldier, while on duty as a sniper in the jungle, peered over a protecting log and was struck in the head by a .25 caliber bullet. The shot was fired by a Japanese sniper from an unknown distance. The soldier was killed instantly on 24 March 1944.

Cursory examination revealed a penetrating wound of the skull, with the wound of entrance in the left orbit. A compound comminuted fracture of the skull with marked brain destruction was present. The large number of dead received on this day prevented a more complete examination.

Figure 198 shows the extent of the wound of entrance.

Case 20.—A soldier of the 129th Infantry was sitting on a log holding a flamethrower when he was struck in the head by a .25 caliber Japanese bullet fired from a distance of 75 yards. His perforated helmet was found lying on the ground. He was killed instantly at 1130 hours on 27 March 1944.

Examination revealed a gutter wound 17.5 x 4 cm. involving the right temporal and frontal regions (fig. 199). There were deep lacerations of the frontal, parietal, and temporal lobes. Disorganized brain tissue filled the wound. Extensive comminution of the cranial vault was found.

Case 21.—A soldier of the 182d Infantry, while crouched, withdrawing from enemy fire, was struck in the back of the neck by a .25 caliber Japanese bullet fired by a sniper from a

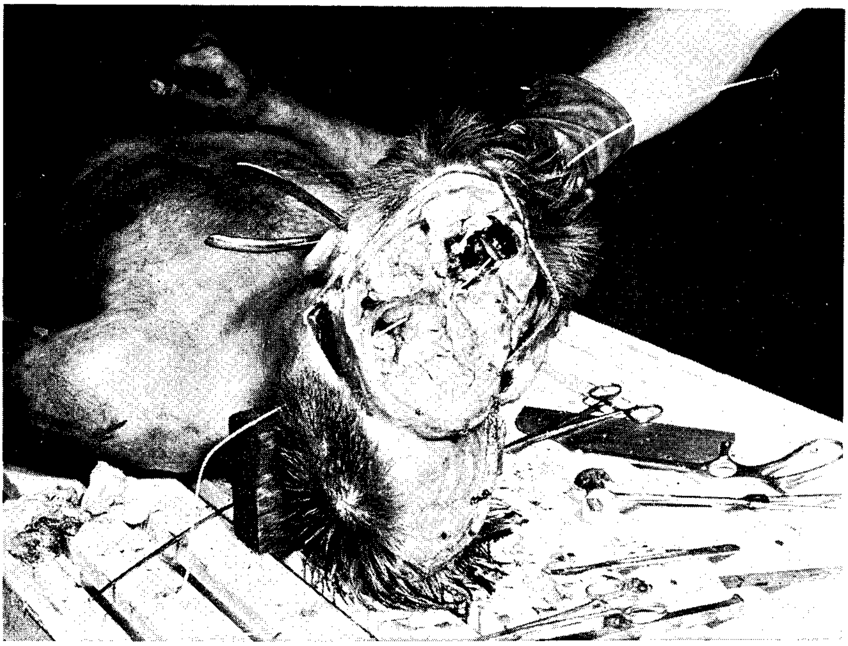


FIGURE 197.—Perforating head wound with catheter in wound track.

FIGURE 198.—Entrance wound in head.

FIGURE 199.—Large defect in skull at site of entrance wound.

distance of 35 yards. He was wounded at 0600 hours on 15 March 1944. His death, about 8 hours later, was accompanied by a terminal hyperthermia.

Examination revealed a perforating wound of the posterior cervical region. The entrance wound (0.5 cm. in diameter) was located to the right of the spinous process of the fifth cervical vertebra and the exit wound (5 cm. in diameter) over the vertebral border of the left scapula. A fracture of the transverse process and lamina of the fifth cervical was discovered. The dura and the cord were intact, but the cord was bulbous and hemorrhagic for a distance of 2 cm. Because of the patient's profound shock, no operative interference was attempted.

Case 22.—A Fijian soldier, while walking toward his own lines returning from patrol, was mistaken for the enemy and shot. He was struck in the right side of the head and abdomen by .30 caliber bullets fired from a Lee-Enfield rifle at a distance of 15 yards. He was wounded at 1810 hours on 23 March 1944 and died at 2055 hours. The soldier died on the operating table, while an attempt was being made to stop bleeding from the brain.

Post mortem examination revealed a gutter wound of the right side of the head extending from the inner canthus of the right eye to the occipital bone. The diffusely lacerated right cerebral hemisphere was herniated through the wound. Bone fragments had been driven into the brain, and extensive hemorrhage was present. The abdominal cavity was filled with blood from severe lacerations of the right kidney and the liver.

Case 23.—A soldier of the 145th Infantry, while standing on the crest of a hill in the open observing mortar fire, was struck by a fragment of a Japanese mortar shell. The shell burst on a pillbox 3 yards distant from the soldier. After injury, the patient walked to the bottom of the hill; he was then placed in an ambulance and taken directly to the 21st Evacuation Hospital. He was wounded at 1800 hours on 10 March 1944. Craniotomy was performed, but the patient died 6 hours later. Death was attributed to severe intracranial hemorrhage.

Examination at autopsy revealed a penetrating wound of the right orbit with destruction of the globe. Craniotomy incision was present. A stellate fracture of the right frontal bone with laceration of the frontal lobe and marked intracranial hemorrhage was found.

Case 24.—A soldier of the 182d Infantry, while walking through the jungle on patrol, was struck by a Japanese machinegun bullet. He was wounded at 1800 hours on 30 April 1944 and arrived at the hospital 3 hours later. A gutter wound of the left frontoparietal region was debrided and closure of the wound attempted. His death at 1210 hours on 2 May 1944 was accompanied by terminal hyperthermia.

Examination revealed a gutter wound 8.7 x 5 cm. in the left frontoparietal region through which an infected fungus protruded. Closure of the wound at the time of operation had not been complete. Portions of the frontal and parietal bones were absent. Bone edges had been rongeured. From the bone margins, stellate fracture lines radiated over the cranial vault. The remnants of the frontal and parietal lobes were grossly infected.

Case 25.—A soldier of the 129th Infantry was standing in an open foxhole when he was struck by a .25 caliber Japanese bullet fired by a sniper from a distance of 75 yards. His helmet was perforated. He was wounded in action at 1430 hours on 24 March 1944 and died 5 hours later, despite shock therapy.

Examination revealed a gutter wound (15 x 7½ cm.) occupying the right parieto-occipital region. Portions of these bones as well as the underlying cerebral hemisphere were absent. A small metal fragment was recovered from the remaining brain tissue and was identified as part of the jacket of a .25 caliber Japanese bullet. The right lateral ventricle was filled with blood. Petechial hemorrhages were present in the left half of the brain. Stellate fracture lines coursed through the bones of the vault.

Case 26.—A soldier of the 129th Infantry was standing in a covered pillbox when a Japanese 90 mm. artillery shell exploded on the ground 7 yards distant destroying one corner of the box. A fragment of the shell struck the soldier, penetrating his skull. He was wounded at 0630 hours on 17 March 1944. Supportive treatment was given and debridement performed. Terminal hyperthermia was present at death, about 12 hours later.

Post mortem examination limited to the head revealed compound linear fractures of the right parietal and temporal bones. Present also were large extra and subdural hemorrhages. A laceration 2.5 x 0.5 cm. with a surrounding area of contusion was present in the right temporal lobe. Destruction of the preoptic area was noted.

Case 27.—A Fijian soldier was behind a tree directing his platoon on patrol when he was struck by a .25 caliber Japanese machinegun bullet fired from a distance of 150 yards. He was killed instantly at 1200 hours on 25 March 1944.

The wound of entrance (2 cm. in diameter) was found over the right fifth intercostal space in the postaxillary line and the exit wound (3 x 1.5 cm.) at the right sternoclavicular articulation. The bullet fractured the fourth, fifth, and sixth ribs, lacerated the middle and upper lobes of the right lung, and fractured the first rib, clavicle, and sternum at its exit. A right hemothorax (2,500 cc.) was present.

Case 28.—A soldier of the 129th Infantry, while running in open terrain toward his foxhole, was struck by a .25 caliber Japanese machinegun bullet fired from a distance of 30 yards. He was killed instantly at 0500 hours on 24 March 1944.

The entrance wound (1.0 cm. in diameter) was located on the right side of the suprasternal notch. The wound of exit was found in the fifth left intercostal space at the costosternal junction. In its course, the bullet fractured the sternum and first rib, severed the aortic arch and trachea, grooved the esophagus, and perforated the lower lobe of the left lung. Massive bilateral hemothorax and mediastinal emphysema were present.

Case 29.—A Fijian soldier, while on patrol standing and digging a hole, was struck in the chest by a fragment of a 90 mm. U.S. shell which burst on the ground 20 yards away. He was killed instantly at 1700 hours on 30 March 1944.

The wound of entry (8.2 x 6.8 cm.) in the posterior aspect of the left side of the chest extended from the level of the third to the seventh rib. The wound of exit (20 x 12.5 cm.) (fig. 200) destroyed the anterior aspect of the chest wall above the nipple. In its course, the

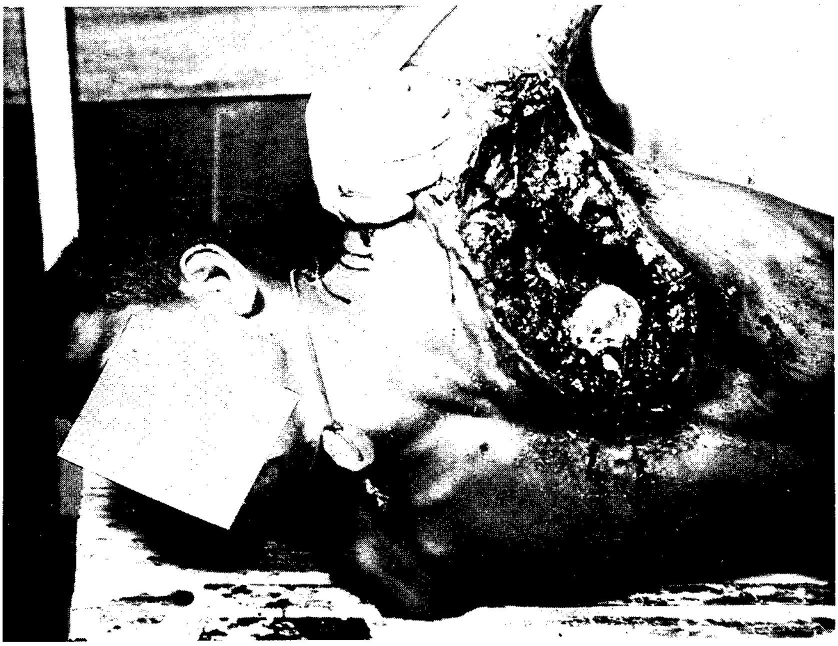


FIGURE 200.—Chest wound of exit.

fragment fractured the left scapula, destroyed all but a small portion of the left lung, and lacerated or severed the heart, thoracic aorta, and inferior vena cava.

Case 30.—A soldier of the 129th Infantry was creeping up on a Japanese pillbox when he was struck by a .25 caliber Japanese rifle bullet fired from a distance of 20 yards. He was killed instantly at 1000 hours.

Examination revealed the wound of entry (3 x 1 cm.) in the fourth right intercostal space in the midaxillary line and the wound of exit (3.8 x 2.5 cm.) in the third left intercostal space in the anterior axillary line. In its course, the bullet fractured the fourth rib and lacerated the left auricle ventricle. There was marked extravasation of blood in both lungs and a massive bilateral hemothorax.

Case 31.—A U.S. soldier, while walking through the jungle on patrol, was struck by a .25 caliber Japanese bullet fired from a distance of 30 yards. He was killed instantly at 1145 hours on 8 April 1944.

Examination revealed the wound of entry (0.6 cm. in diameter) in the anterior left second intercostal space in the midclavicular line and the wound of exit (2.5 cm. in diameter) in the posterior right fifth intercostal space in the posterior axillary line. In its course, the bullet perforated the upper lobe of the left lung, pericardium, pulmonary artery, the upper lobe of the right lung, and fractured the right fifth rib in its exit. Hemothorax (left, 400 cc.; right, 1,500 cc.) and hemopericardium were present.

Case 32.—A soldier of the 117th Engineer Combat Battalion, while walking and covering the evacuation of a casualty, was struck by a .25 caliber Japanese bullet fired from a distance of 35 yards. He was killed instantly at 1300 hours on 24 March 1944.

Examination revealed a perforating wound of the chest. The wound of entry (0.5 cm. in diameter) was located in the anterior axillary line in the fourth left intercostal space and the wound of exit in the seventh intercostal space in the right midaxillary line. In its course, the bullet grooved the anterior medial border of the lower lobe of the left lung, pierced the

pericardial sac, right ventricle, and middle and lower lobes of the right lung. Bilateral hemothorax (2,500 cc.) and hemopericardium were present.

Case 33.—A soldier of the 129th Infantry, while walking beyond the perimeter, stepped on a U.S. landmine and was killed instantly at 1015 hours on 12 April 1944.

Examination revealed seven penetrating and perforating wounds. A chest wound was responsible for instantaneous death. One fragment entered the left side of the chest through the second rib in the midclavicular line and made its exit through the right sixth intercostal space in the midaxillary line. In its course, the fragment fractured the second rib, lacerated the upper lobe of the left lung, avulsed the anterior wall of the ascending aorta, perforated the middle lobe of the right lung, lacerated the lower lobe of the right lung, and fractured the sixth and seventh ribs at its exit. There were 2,000 cc. of blood in each pleural cavity. A compound comminuted fracture of the mandible was present. In addition, wounds of the right forearm and arm, left frontal region, and left thigh were found.

Case 34.—A soldier of the 182d Infantry was in an open foxhole with his "buddy," when he was struck by fragments of a U.S. 37 mm. shell which burst on the ground 3 yards distant. The other occupant was not injured. This soldier was killed instantly at 0710 hours on 24 March 1944.

Examination revealed a perforating wound of the chest. The entrance wound (7.5 x 4 cm.) was in the right third intercostal space at the costosternal junction and the exit wound (6.5 x 4 cm.) in the left fourth intercostal space in the midaxillary line. The fragment severed the left intercostal and the internal mammary arteries. The lower lobe of the left lung and the middle lobe of the right lung were contused, and massive hemopericardium and left hemothorax were present. The right ventricle and auricle were lacerated, but the pericardial sac was intact.

Case 35.—A U.S. soldier was standing in a covered pillbox when he was struck by a fragment of a Japanese mortar shell which came through the peepslit. The shell burst on the ground at a 25-yard distance. He was killed instantly at 2000 hours on 23 March 1944.

Examination revealed a penetrating wound of entry (2.5 cm. in diameter) in the right side of the chest in the second intercostal space, anterior axillary line. The fragment (fig. 201) in its course fractured the second rib, perforated the upper lobe of the right lung, partially severed the thoracic aorta, perforated the lower lobe, fractured the eighth rib, and lodged in the subcutaneous tissues over the ninth rib in the right midscapular line. Massive hemothorax was present.

Case 36.—A soldier of the 129th Infantry was killed in action in the 129th sector at 2140 hours on 25 March 1944. He was struck by fragments from a Japanese mortar shell. Other circumstances are not known.

Examination revealed a large entrance wound (12.5 x 10 cm.) on the left extending from the nipple to the midaxillary line and from the level of the third to the sixth rib (fig. 202). The fragments shattered the fifth and sixth ribs creating an opening (4 cm. in diameter) into

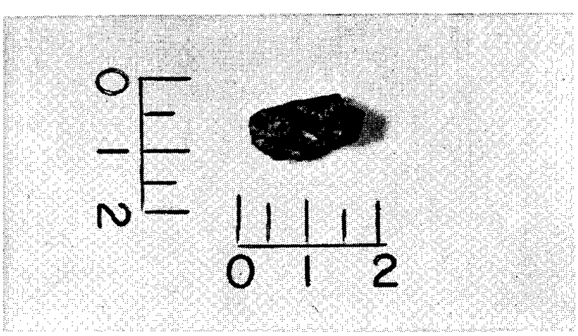


FIGURE 201.—Mortar shell fragment recovered from chest wounds.

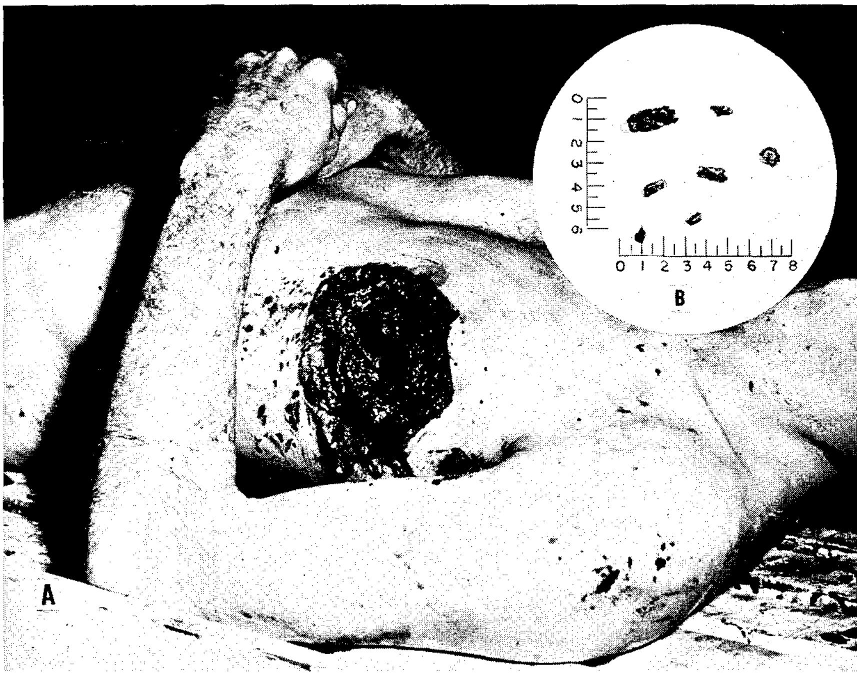


FIGURE 202.—Chest wound. A. Wound of entrance. B. Recovered mortar shell fragments.

the left side of the pleural cavity. Bone fragments were driven into the lower lobe of the left lung producing an irregular laceration. A small metal fragment penetrated the left dome of the diaphragm, and a button from the soldier's jacket was found in the omentum. A lacerated wound (3.2 x 3 cm.) was found in the left ventricle. The seventh and ninth ribs posteriorly were fractured, and in the subcutaneous tissue in this region five metal fragments were found. Massive left hemothorax was present.

Case 37.—A soldier of the 148th Infantry, on 1 April 1944, having been struck in the arm by a Japanese .25 caliber bullet fired from a distance of 7 yards, walked back toward the first aid station. En route he was mistaken for the enemy and was struck in the chest with a .30 caliber bullet fired from a U.S. M1 rifle from a distance of 30 yards. He was killed instantly.

Examination revealed a perforating wound of the right side of the thorax and a wound of the right shoulder. The entrance wound in the chest (0.5 cm. in diameter) was located in the first intercostal space in the midclavicular line and the exit wound (2.5 cm. in diameter) at the level of the 12th rib in the midscapular line. The bullet perforated the upper and lower lobes of the right lung and fractured the 10th and 11th ribs. Massive hemothorax was present. The penetrating wound of the left shoulder (0.5 cm. in diameter) involved only the left deltoid muscle. No foreign body was found.

Case 38.—A Fijian soldier, while on patrol, was kneeling behind a rotten log when struck by a .25 caliber Japanese bullet fired from a distance of 5 yards. He was killed instantly at 1545 hours on 31 March 1944.

The entrance wound (0.5 cm. in diameter) was found over the sternum at the junction of the manubrium with the body and the exit wound (1.2 cm. in diameter) in the left eighth intercostal space in the anterior axillary line. In its course, the bullet fractured the sternum,

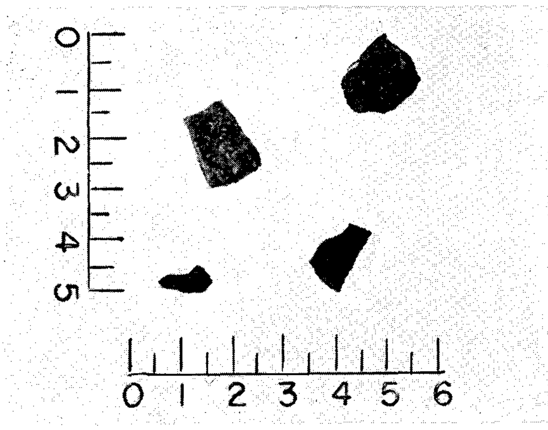


FIGURE 203.—Japanese hand grenade fragments recovered from chest wound.

perforated the aorta, pulmonary artery and lower lobe of the left lung, and fractured the eighth rib in making its exit. Massive bilateral hemothorax was present.

Case 39.—A soldier of the 129th Infantry, while attacking a Japanese pillbox, was killed instantly by the pointblank explosion of a Japanese hand grenade at 0800 hours on 24 March 1944.

Examination revealed multiple penetrating wounds of the chest, head, face, and abdomen. One fragment, entering the thorax through the third right intercostal space in the nipple line, had lacerated and lodged in the upper lobe of the right lung. A massive hemothorax was present. The 12th dorsal vertebra and the mandible and temporal bones were fractured.

The recovered fragments are shown in figure 203.

Case 40.—A soldier of the 164th Infantry, while walking through the jungle on patrol, was struck by .25 caliber Japanese bullets fired from a distance of 5 yards. He was killed instantly at 1130 hours on 29 March 1944.

Examination of the chest revealed an entrance wound (1.8 cm. in diameter) in the posterior aspect of the left side of the chest in the seventh intercostal space and an exit wound (3.8 cm. in diameter) in the left midclavicle. In its course, the bullet had fractured the fourth, fifth, sixth, seventh, and eighth ribs in the axillary line, severely lacerated both lobes, and fractured the clavicle at its exit. Massive left hemothorax was present. Another bullet had penetrated the soft tissues of the left thigh, making its entrance through the lateral side of the upper third. It was found in the vastus medialis. A third bullet perforated the left foot through the first metatarsophalangeal joint.

Figure 204 shows the bullet recovered from the thigh.

Case 41.—A U.S. soldier, while kneeling in the open administering first aid to a casualty, was struck by a .25 caliber bullet fired by a sniper from a distance of 35 yards. He was killed instantly at 1300 hours on 24 March 1944.

Examination revealed a perforating wound of the left side of the chest. The entrance wound (0.5 cm. in diameter) lay over the third rib anteriorly 4 cm. from the midline and the exit wound (1.5 x 1 cm.) over the angle of the left scapula. In its course, the missile fractured the third rib and lacerated the hilum of the left lung severing a large branch of the pulmonary artery and a secondary bronchus. The upper lobe of the left lung was severely lacerated. Hemothorax (1,500 cc.) was present on the left. Blood exuded from the mouth.

Case 42.—A soldier of the 129th Infantry, while squatting in a shallow hole on patrol, was struck by a fragment of a U.S. artillery shell which burst on the ground 5 yards distant. He was killed instantly at 1230 hours on 29 March 1944.

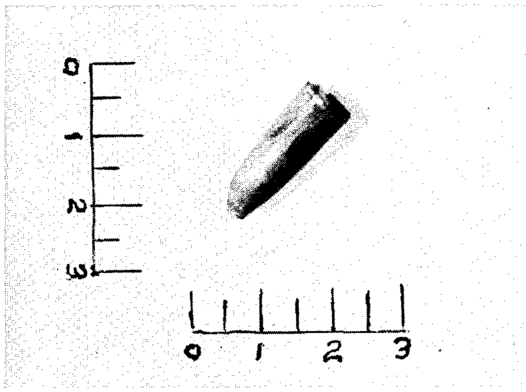


FIGURE 204.—Japanese .25 caliber bullet recovered from thigh. Note deformity of tip of bullet.

Examination revealed a penetrating wound of the right side of the chest. The wound of entrance (3.7 cm. in diameter) was situated in the third right intercostal space in the midaxillary line. The fragment fractured the fourth rib, perforated the middle lobe of the right lung, the right auricle, the right ventricle, and lodged in the lower lobe of the left lung. Hemopericardium and massive right hemothorax were present.

Figure 205 shows the only fragment recovered.

Case 43.—A soldier of the 129th Infantry was killed in action in the 129th sector. He was struck by .25 caliber Japanese bullets and killed instantly at 1345 hours on 24 March 1944.

The thoracic entrance wound (0.5 cm. in diameter) was found in the sixth right intercostal space in the posterior axillary line and the exit wound in the eighth left intercostal space in the midscapular line. The bullet produced fractures of the right sixth, seventh, and eighth ribs, severe lacerations of the posterior surface of the middle and posterior lobes of the right lung, fractures of the bodies of the seventh and eighth vertebras, transection of the spinal cord, perforation of the lower lobe of the left lung, and fracture of the left eighth rib in the posterior axillary line. A flattened bullet, 1.2 x 1 x 0.2 cm., was recovered in this region. Massive bilateral hemothorax was present. A severe comminuted fracture of the middle third of the right femur had resulted from another bullet. The wound of entrance on the thigh was very small.

Case 44.—A Fijian soldier, while on patrol kneeling behind a tree and firing at the enemy, was struck by a .25 caliber Japanese bullet fired from a distance of 20 yards. He was killed instantly on 31 March 1944.

The wound of entrance (0.5 cm. in diameter) was located in the left fourth intercostal space in the parasternal line and the exit wound (3.7 cm. in diameter) in the left sixth intercostal space in the midaxillary line. The bullet produced irregular lacerations of the right and left ventricles and perforated the upper lobe of the left lung. Massive hemothorax and hemopericardium were present.

Case 45.—A soldier of the 129th Infantry stepped out of his pillbox and was struck by a .25 caliber Japanese sniper bullet from a distance of 25 yards. He fell back into the pillbox and died instantly at 0730 hours on 25 March 1944.

Examination revealed a penetrating wound of the anterior aspect of the left side of the chest wall. The entrance wound (1 cm. in diameter) was found in the fourth intercostal space at the costochondral junction. Demonstrated at autopsy were a fracture of the fourth rib and sternum, right hemothorax (3,000 cc.), perforation of the right auricle and ventricle, and a laceration of the hilus of the right lung.

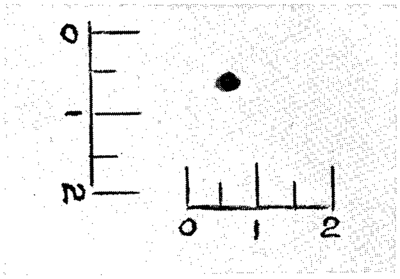


Figure 205.—U.S. artillery shell fragment recovered from chest wound.

Figure 206 shows the flattened .25 caliber bullet which was found lying free in the right side of the pleural cavity.

Case 46.—A soldier of the 129th Infantry, while sitting in the cleared open jungle, was struck by fragments of a 90 mm. Japanese shell which exploded on the ground at a distance of 20 yards. He was killed instantly at 1425 hours on 25 March 1944.

Examination disclosed an entrance wound (20 x 10 cm.) over the left scapula and an exit wound (2 cm. in diameter) on the left arm 6 cm. below the acromion process (fig. 207). The head of the left humerus was shattered, and there were fractures of the third, fourth, fifth, sixth, seventh, and eighth ribs in the midaxillary line and the fifth, sixth, and seventh ribs in the anterior axillary line. The parietal pleura was torn, both lobes of the left lung were severely lacerated, and the left scapula was extensively comminuted. A hemothorax (3,500 cc.) was present.

Figure 207A shows the large wound of entrance and figure 207B the small wound of exit of one of the fragments. Several small metal fragments recovered from the scapular area are shown in figure 207C.

Case 47.—A New Zealand soldier, while walking through the jungle on patrol, was struck by a .25 caliber Japanese sniper bullet fired from a distance of 30 yards. He was killed instantly at 0930 hours on 14 March 1944.

Examination revealed a perforating wound of the neck with the entrance (0.6 cm. in diameter) situated below the tip of the left mastoid and the exit (4.3 cm. in diameter) below the right acromioclavicular articulation. In its oblique course, the bullet perforated the third cervical vertebra, severed the spinal cord, fractured the first, second, and third ribs at their costovertebral junctions, entered the pleural cavity, perforated the upper lobe of the right lung, and made its exit between the clavicle and scapula. Present on the right was a hemothorax of 2,000 centimeters.

Case 48.—A Fijian soldier, while moving forward on patrol in a crouched position, was struck by a fragment of a 90 mm. Japanese mortar shell which burst on the ground 10 yards away. He died en route to the hospital at 1000 hours on 26 March 1944.

Examination revealed a penetrating wound of the posterior aspect of the right side of the chest. The fragment entered 8 cm. from the midline at the level of the sixth dorsal vertebra through a wound 1.5 cm. in diameter. It coursed under the skin to enter the left side of the chest in the sixth intercostal space, 5 cm. from the midline. The seventh rib was fractured at this point. The posterior surface of the lower lobe of the left lung was severely lacerated. A metal fragment was recovered from the pleural cavity. A left hemothorax (2,000 cc.) was present.

Case 49.—A soldier of the 129th Infantry, while walking behind a tank, was struck twice by .25 caliber Japanese bullets fired from a distance of 40 yards. He was killed instantly at 1030 hours on 24 March 1944.

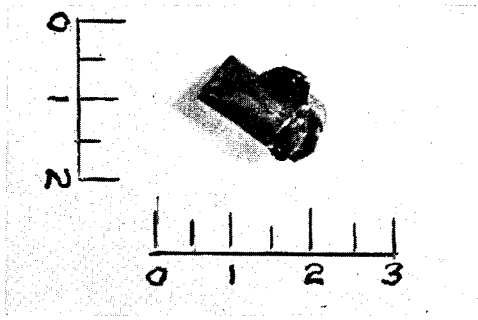


FIGURE 206.—Deformed Japanese rifle bullet recovered from pleural cavity.

Examination revealed two penetrating wounds of entry (4 x 2.4 cm. and 3.5 x 2 cm. in diameter); one through the right and the other through the left second costosternal junction. Post mortem examination showed compound comminuted fractures of the second ribs (right and left) and sternum, severance of the right intercostal and internal mammary arteries, bilateral hemothorax, complete transection of the aortic arch and right pulmonary artery and vein, perforation of the left auricle, laceration of the upper lobe of the right lung, incomplete division of the esophagus and trachea at the level of bifurcation, and perforation of the body of the seventh thoracic vertebra.

Case 50.—A soldier of the 129th Infantry was prone in the open behind a tank assault when he was struck by a .25 caliber Japanese bullet fired from a distance of 100 yards. He was wounded at 1100 hours on 24 March 1944. Several hours later, thoracotomy was performed at the 21st Evacuation Hospital, and a lacerated left lung was sutured. He received penicillin daily and seemed to improve. Death from pulmonary embolus occurred suddenly at 0730 hours on 28 March 1944.

Examination revealed a curved incision (22.5 cm. in length) in the posterior aspect of the left side of the chest wall extending from the fifth dorsal vertebra to the axillary line. A left fibrinous pleuritis with effusion (500 cc.) was present. A laceration of the lower lobe of the left lung had been closed by suture. The lung was congested, and a thrombus was found lodged in the pulmonary artery.

Case 51.—A soldier of the 129th Infantry, while standing in an open foxhole, received a serious wound at 1500 hours on 27 March 1944 from a fragment of a U.S. 4.2-inch mortar shell which burst on the ground 3 yards away. At the portable surgical hospital, the sucking wound of the chest was closed. The following day, the patient was transferred to the 21st Evacuation Hospital. Upon admission to the ward, dehiscence of the wound was present. A second operation was performed and bone fragments were removed from the lung and bleeding was controlled. The patient never regained consciousness and died at 1700 hours on 30 March 1944.

Autopsy revealed an oblique operative incision 17.5 cm. long, extending from the third dorsal spine to the ninth rib, in the posterior aspect of the right side of the chest. The right scapula and the seventh and eighth ribs were fractured. A right hemothorax was found, and sutures were present in the middle and lower lobes of the right lung. The lungs were emphysematous, and there was marked dilatation of the right ventricle. Death was attributed to heart failure. In this case, death may have been precipitated by the rapid administration of necessary intravenous fluids in the presence of some pulmonary obstruction.

Case 52.—A soldier of the 129th Infantry, while walking in a crouched position following a tank assault, was struck by a .25 caliber Japanese bullet fired from a distance of 25 yards. He was wounded at 1245 hours on 24 March 1944 and died 24 hours later. Death resulted from transection of the thoracic spinal cord and was associated with terminal hyperthermia.

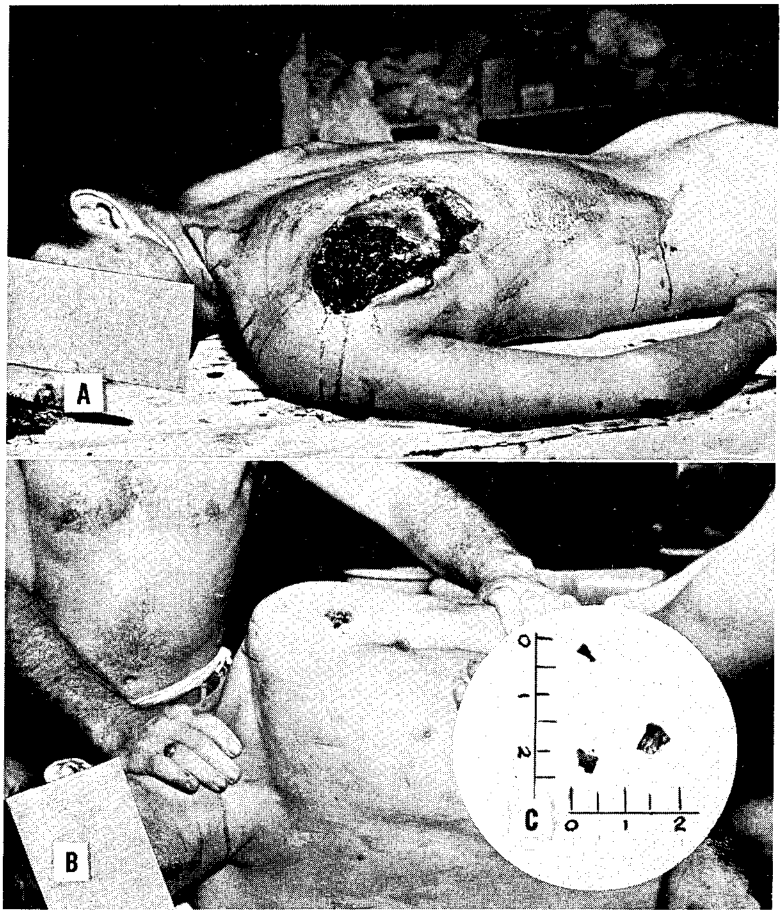


FIGURE 207.—Wound of scapular area. A. Wound of entrance. B. Wound of exit. C. Metal fragments recovered from scapular area.

The wound of entrance (3 cm. in diameter) was located in the center of the left supraclavicular region. The bullet entered the chest through the first intercostal space, fractured the first and second ribs, and produced a gutter wound in the upper lobe of the left lung. The body of the second dorsal vertebra was fractured and the spinal cord severed at the same level. A massive left hemothorax was found. The bullet was not recovered.

Case 53.—An airman of the 13th Army Air Force shot himself with a .30 caliber carbine at 1300 hours on 4 April 1944. He arrived at the hospital in 10 minutes, was given three units of plasma, and underwent immediate thoracotomy. An attempt was made to suture the lacerations of the lung, but the patient died on the table from shock due to hemorrhage.

Post mortem examination revealed an entry wound 6 mm. in diameter in the anterior aspect of the left side of the chest, 10 cm. from the midline in the seventh intercostal space. The wound of exit, located posteriorly in the third intercostal space 5 cm. from the midline, was 2.5 cm. in diameter. The bullet in its course lacerated the lower lobe of the left lung. A contusion of the left ventricle and a hemothorax (1,000 cc.) were found.

Case 54.—A soldier of the 129th Infantry, while prone firing at the enemy, was hit twice by .303 caliber bullets fired from a Japanese machinegun from a distance of 35 yards.

He was wounded at 0830 hours on 24 March 1944 and taken to the hospital immediately. After adequate shock therapy, the chest wound was debrided and closed and laparotomy performed. The patient died at 0645 hours on 28 March 1944 of pulmonary edema.

Post mortem examination revealed two wound tracks. One bullet produced an entry wound (3.2 x 2.5 cm.) lateral to the spinous process of the first lumbar vertebra; this missile coursed superiorly and laterally, fractured the 12th rib, perforated the diaphragm, and was found lodged under the 11th rib in the midaxillary line. The other wound was perforating in type with its entrance (1.2 cm. in diameter) located 1 cm. below the right clavicle at the outer third and exit (17.9 cm. in length) located 9 cm. to the left of the 11th dorsal vertebra. In its course, this bullet produced a temporary cavity injury of the right lung, perforated the lower lobe of the left lung, and fractured the ninth rib. Edema of the lower lobe of the left lung, fibrinous pleuritis, and hemopneumothorax were present. The right lung was diffusely discolored. The abdominal examination was negative, as the bullet had traversed the retroperitoneal space.

Case 55.—A soldier of the 145th Infantry, while kneeling in the open firing at the enemy, was struck by a .25 caliber Japanese bullet fired from a distance of 15 yards. He was wounded on 16 March 1944. Thoracotomy was performed at the 21st Evacuation Hospital several hours later. The lower lobe of the right lung was removed, the diaphragm closed, and bleeding from the perforation in the body of the 12th dorsal vertebra was controlled by electrocoagulation. The spinal cord was severed at the level of 12th dorsal. The patient was evacuated from the island on the eighth postoperative day. He developed an empyema at the 31st General Hospital. Surgical drainage of the empyema was established. In spite of adequate drainage, penicillin, and supportive therapy, the patient died from the infection on 25 April 1944.

Post mortem examination revealed gross infection of the right side of the pleural cavity. The remaining upper and middle lobes were shrunken and adherent and the pleura markedly thickened. The right lower bronchus communicated with the pleural cavity. The spinal cord was transected at the level of the fracture of the 12th dorsal vertebra. The diaphragm had been repaired. Generalized intestinal distension and focal necrosis of the liver were present.

Case 56.—A Fijian soldier, while crouching and advancing on patrol, was shot through the left side of the chest by a .25 caliber Japanese bullet from a distance of 30 yards. He was wounded in the morning of 30 March 1944. Upon arrival at the 21st Evacuation Hospital, immediate thoracotomy was performed in an attempt to control pulmonary bleeding. The patient died several hours later (1420 hours on 30 March 1944) of acute cardiac dilatation and hemorrhage. The cardiac dilatation was thought to be secondary to obstruction of the pulmonary circulation (see Case 51, p. 398.)

Post mortem examination showed a wound of entry (1.2 cm. in diameter) through the second left intercostal space above the costosternal junction. The wound of exit had been closed at the time of operation. A curved anteriolateral incision from the second to sixth rib was noted. Lacerations of the upper and lower lobes had been sutured. The right heart was markedly dilated. Moderate left hemothorax was present.

Case 57.—A soldier of the 920th ABS, while stepping out of a truck, was hit by fragments of a Japanese artillery shell which burst on the ground 2 yards away. He was wounded at 0600 hours on 24 March 1944. Within an hour, he was at the 52d Field Hospital, and the wound on the left side of the chest was excised, the lung sutured, and the chest closed. In addition, a loop colostomy of the sigmoid was done because of a perforation of the colon. The patient died several hours later from massive pulmonary hemorrhage.

Examination revealed penetrating wounds of the chest and left gluteal region. The entry wound in the anterior aspect of the left side of the chest through the fifth interspace had been excised and closed. The fifth and sixth ribs were fractured. Massive hemothorax was present. A large mattress suture partially closed the laceration in the lower lobe of the left lung. The abdominal cavity had been entered by a fragment which perforated the left wing of the ilium leaving a wound of entrance 7.5 cm. in diameter. Fragments

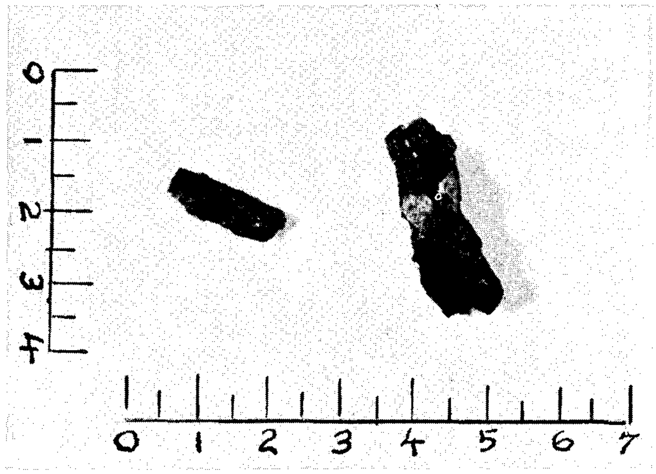


FIGURE 208.—Japanese artillery shell fragments recovered from chest wall.

of bone had been dispersed extensively lacerating the gluteal muscles. As just stated, the perforation of the sigmoid colon had been treated by exteriorization through a left rectus incision.

Figure 208 shows metal fragments removed from the chest wall.

Case 58.—A soldier of the 182d Infantry, while crawling through the jungle on patrol, was struck by .25 caliber Japanese machinegun bullets. He was wounded at 2100 hours on 2 May 1944 and reached the hospital within 3 hours. Thoracotomy was decided upon because of intrathoracic bleeding. The patient died on the operating table during induction of the anesthetic at 0515 hours on 3 May 1944.

Examination revealed a perforating wound of the left side of the chest and a penetrating wound of the right axilla. One entrance wound (1.2 cm. in diameter) into the chest was situated in the left midscapular region and the exit wound (5 x 2 cm.) in the left supraclavicular fossa. In its course, the bullet fractured the scapula and the second, third, and fourth ribs. The broken ribs had severely lacerated the pleura and the upper lobe of the left lung. The bullet had not entered the pleural cavity. A massive left hemothorax was present. Another bullet penetrated the apex of the right axilla through a wound 3.7 cm. in diameter and in its course severed the radial and median nerves and fractured the upper third of the humerus. The bullet was found in the belly of the triceps muscle.

Case 59.—A soldier of the 24th Infantry, while running forward in a skirmish line, was struck by .25 caliber Japanese machinegun bullets fired from a distance of 75 yards. He was killed instantly at 1100 hours on 14 April 1944.

Examination revealed multiple wounds. A missile which produced a penetrating wound of the right side of the abdomen and traversed the right thorax was responsible for rapid death. This bullet entered the right kidney region opposite the spinous process of the second lumbar vertebra. In its course, it lacerated the lower pole of the right kidney, perforated the hepatic flexure of the colon, right lobe of the liver and diaphragm, lacerated the lower right lobe of the lung, and fractured the 8th, 9th, 10th, 11th, and 12th ribs in the posterior axillary line. Hemoperitoneum and a right hemothorax (1,000 cc.) were present. The bullet was recovered in the subcutaneous tissue. Another bullet perforating the neck entered the right side in the posterior cervical triangle and made its exit below the tip of the left mastoid process. The trachea was severed at the level of the cricoid cartilage. Another bullet struck the left side of the face (fig. 209) producing a gutter wound 12.5 x 3.7 x 0.25 cm., which destroyed the left temporomandibular joint. Present also was a perforating wound in the right infraclavicular space with fracture of the right clavicle.

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FIGURE 209.—Gutter wound of left side of face and neck.

FIGURE 210.—Deformed .25 caliber machinegun bullet recovered from chest wall.

Figure 210 shows the distorted bullet and a part of the jacket removed from the right side of the chest wall.

Case 60.—A soldier of the 129th Infantry, while crouching following a tank assault, was shot by a .25 caliber Japanese machinegun bullet from a distance of 25 yards. He was killed instantly at 0800 hours on 13 March 1944.

Examination showed an entrance wound (0.6 cm. in diameter) through the anterior aspect of the right side of the chest in the second intercostal space in the nipple line and an exit wound (7.5 cm. in diameter) through the left loin above the wing of the ilium. In its oblique course, the bullet perforated or severed the middle lobe of the right lung, the diaphragm, the right lobe of the liver, the pancreas at the junction of the head and body, the transverse duodenum, the jejunum, and the left colon at the sigmoid junction. Moderate hemothorax and hemoperitoneum were present.

Case 61.—A soldier of the 129th Infantry, while standing in a foxhole covered by light roofing, was killed instantly by the direct burst of a Japanese mortar shell; 4 other men were wounded. The soldier was killed at 0530 hours on 24 March 1944.

Multiple penetrating wounds of the back, chest, and abdomen were sustained. A large chest wound caused death. The wound of entrance was 9 cm. in diameter and situated in the posterior aspect of the left side of the chest 2.5 cm. from the spinous processes of T–11 and T–12. In its course, this fragment fractured the fifth and sixth ribs anteriorly and the 8th, 9th, and 10th ribs posteriorly; fragmented the lower lobe of the left lung; perforated the diaphragm; disrupted the spleen; and transected the descending colon. The bodies of the 11th and 12th dorsal vertebras were badly comminuted. Massive left hemothorax and hemoperitoneum were present.

Figure 211 shows metal fragments identified as parts of a first aid box.

Case 62.—A soldier of the 129th Infantry, while in a pillbox, was surrounded by Japanese. He was killed by fragments of a Japanese hand grenade which exploded at point-blank range; 2 other men in the pillbox were wounded. The soldier died instantly at 0800 hours on 24 March 1944.

Examination revealed multiple penetrating wounds of the chest, right thigh, right leg, and right arm. The wounds of the thorax were fatal. There were multiple, small penetrating wounds through the right posterior axillary line from the 7th to 12th rib. The largest was 1.2 cm. in diameter. Small fragments perforated the lower lobe of the right lung and diaphragm and produced a laceration (7 x 3 x 1.3 cm.) in the dome of the liver.

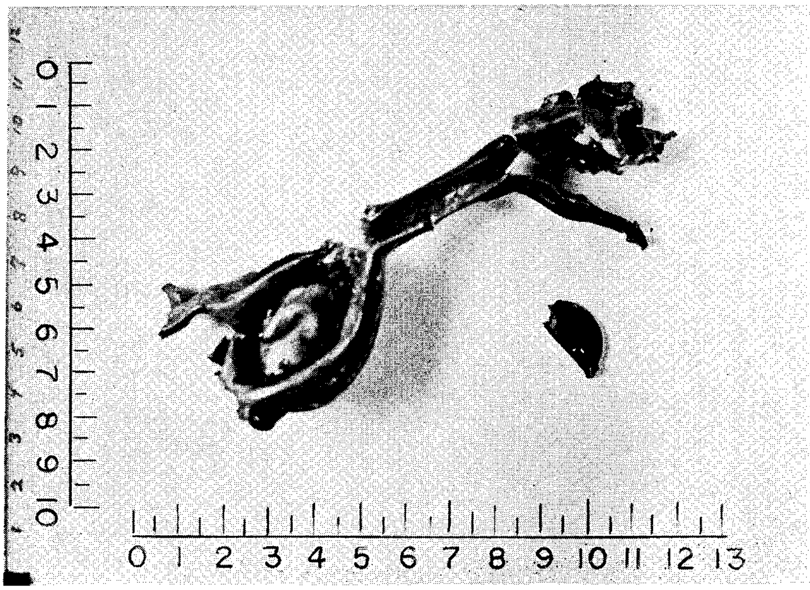


FIGURE 211.—Recovered metal fragments identified as parts of first aid box.

Massive right hemothorax and moderate hemoperitoneum were present. The remaining wounds were not extensive.

Figure 212 shows the recovered grenade fragments.

Case 63.—A Fijian soldier, while running on patrol, stepped on a U.S. landmine and was killed instantly at 1100 hours on 26 March 1944.

Examination revealed nine penetrating wounds. Three fragments entered the left side of the chest anteriorly in the first intercostal space in the nipple line and perforated or severed the upper lobe of the left lung, pulmonary artery, aortic arch, trachea, lower lobe of the right lung, diaphragm, and liver. Two metallic fragments were found in the liver. Hemothorax (left, 2,500 cc., and right, 250 cc.) was present. In addition, there were wounds of the left elbow, thigh, cheek, chin and eye, and an extensive gutter wound of the left buttock.

Case 64.—A soldier of the 21st Reconnaissance Troop was killed by a U.S. hand grenade which exploded in his pocket, while returning from patrol. He was killed instantly at 0920 hours on 25 April 1944.

Examination revealed 12 penetrating wounds, 4 of which penetrated the thorax. The fragments entered the left side of the chest in the midaxillary line at the levels of the fourth, sixth, and ninth ribs. The left fourth, fifth, and sixth ribs were fractured; the diaphragm, spleen, and pancreas were lacerated; and the stomach was perforated in two places. Massive left hemothorax and hemoperitoneum were present. One grenade fragment was recovered from the pleural cavity and two fragments from the lumen of the stomach. The remaining wounds were in the upper extremities.

Figure 213 shows the recovered fragments, the largest of which was removed from the thorax.

Case 65.—A Japanese soldier (unknown) was killed on 22 March 1944 by fragments from an HE shell.

Examination revealed an entrance wound (2 cm. in diameter) in the 11th left intercostal space. The fragments in their course lacerated the lower lobe of the left lung and diaphragm and spleen and were found in the subcutaneous tissue at the exit wound. Present also were a bilateral hemothorax and a hemoperitoneum (300 cc.).

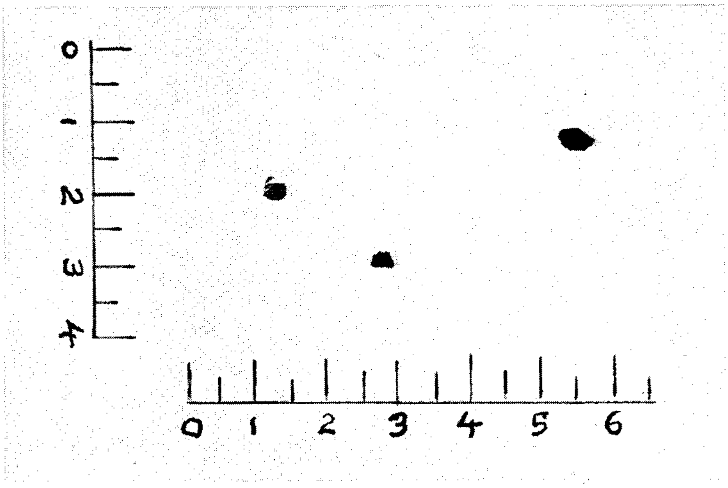


FIGURE 212.—Fragments of Japanese hand grenade recovered from multiple wounds.

Case 66.—A soldier of the 21st Reconnaissance Troop, while crouching and moving forward in a skirmish line, was struck three times by .25 caliber Japanese machinegun bullets fired from a distance of 20 yards. He was killed instantly at 1600 hours on 27 March 1944.

An abdominal wound was responsible for death. The wound of entrance (0.5 cm. in diameter) was placed in the midline 7.5 cm. above the umbilicus. This bullet severed the abdominal aorta and fractured the first lumbar vertebra. Another bullet perforated the right deltoid muscle and entered the right side of the thoracic cavity through the fourth intercostal space in the anterior axillary line. The fifth, sixth, and seventh ribs were fractured, the lower lobe of the lung and the dome of the diaphragm were lacerated, the liver was perforated, and the right kidney was fragmented. There were also superficial wounds of the left hip and left forearm.

Case 67.—A soldier of the 129th Infantry was struck by a .25 caliber Japanese bullet fired by a sniper from a distance of 25 yards. His position when hit was not known. He was killed instantly at 1300 hours on 24 March 1944.

The bullet entered the left side of the thorax through a wound (0.5 cm. in diameter) in the anterior fourth intercostal space in the anterior axillary line and made its exit through a wound (2.5 x 1.5 cm.) in the right sixth intercostal space in the midaxillary line. The bullet in its course perforated the upper lobe of the left lung, left ventricle, right ventricle, lower lobe of the right lung, and the diaphragm and produced an irregular laceration in the vertex of the liver 7.5 cm. in length before making its exit. Massive bilateral hemothorax and hemoperitoneum were found.

Case 68.—A soldier of the 132d Infantry, while on patrol entering a Japanese pillbox, was struck by a .25 caliber Japanese bullet fired at close range. He was wounded at 1700 hours on 29 March 1944. Laparotomy was performed several hours later at the clearing station. At operation, the left side of the diaphragm was repaired, and a transverse colostomy was performed after suture of a perforation in the splenic flexure of the colon. The patient died at 0600 hours on 4 April 1944 with signs of cardiorespiratory failure.

Examination revealed a penetrating bullet wound of the left side of the chest entering the sixth intercostal space in the posterior axillary line. Transverse colostomy had been performed through an upper left rectus incision. The seventh, eighth, and ninth ribs were fractured, and moderate left hemothorax was present. The lower lobe of the left lung was discolored. The pericardial sac contained a small amount of blood, although it had not

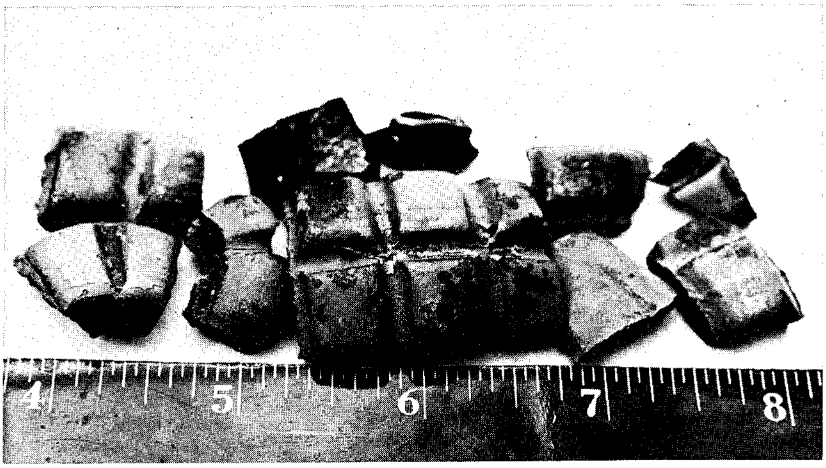


FIGURE 213.—Fragments of U.S. hand grenade recovered from multiple wounds.

been perforated. An area of epicardial ecchymosis was found on the left ventricle.[19] Present also were a laceration of the spleen and an explosive wound of the left kidney with a large hematoma. A perforation in the splenic flexure of the colon had been sutured. The repair of the diaphragm was unsuccessful.

Case 69.—A soldier of the 129th Infantry, while leading his platoon against the enemy, was struck by a .25 caliber bullet fired from a short distance. He was wounded at 0900 hours on 13 March 1944. An hour later, debridement and closure of the chest wound were done at the 21st Evacuation Hospital. He was evacuated by air on 15 March and died on 21 March 1944, at the 9th Station Hospital, of secondary hemorrhages from the left lung and spleen.

Post mortem examination revealed a perforated wound of the left elbow and a compound fracture of the humerus. The same bullet had entered the left side of the chest in the sixth intercostal space in the posterior axillary line and made its exit in the left seventh intercostal space. The thoracotomy incision was well healed. The left side of the pleural cavity contained a liter of blood. Both lobes of the left lung were lacerated, and the diaphragm, spleen, and kidney were perforated. Old and fresh blood were present in the peritoneal cavity. A retroperitoneal hematoma was well organized.

Case 70.—A Fijian soldier, while crouching in a skirmish line on patrol, was struck by fragments of a Japanese mortar shell which burst on the ground 20 yards distant. He was wounded on 29 March 1944. Splenectomy, exteriorization of the colon, closure of a chest wound, and debridement of an arm wound were performed the same day. He died at 2215 hours on 30 March 1944 of shock and hemorrhage.

Examination revealed wounds of the chest, abdomen, and left arm. A linear incision extended in the ninth left intercostal space from the nipple to the axillary line. The pleural cavity contained 3,000 cc. of blood. Fibrinous pleuritis, congestion of the lung, and dilatation of the right heart were found. The rent in the left side of the diaphragm was incompletely closed. A left rectus incision was present through which protruded the exteriorized loop of the perforated transverse colon. A small amount of free blood was present in the abdominal cavity. The spleen had been removed. The body and tail of the pancreas were lacerated. An explosive wound of the left kidney and a large retroperitoneal hematoma were found. Present also in the lower third of the left arm was the wound of a severe compound comminuted fracture of the humerus.

[19] This type of injury is similar in origin to the pulmonary hemorrhage seen at some distance from the permanent wound track and is a result of the formation of the temporary cavity during the passage of high-velocity missiles.—J. C. B.

Case 71.—A soldier of the 37th Reconnaissance Troop, while walking in a crouched position through thick jungle on patrol, was struck in the left lumbar region by a Japanese .25 caliber bullet fired from a distance of 25 yards. He was wounded at 1815 hours on 4 March 1944. Laparotomy was performed at the 21st Evacuation Hospital several hours later. Perforations in the bowel were sutured, and an attempt was made to arrest hemorrhage from a laceration in the liver. The patient died at 1615 hours on 5 March 1944 from shock and hemorrhage.

Examination revealed a wound of entry (0.5 cm. in diameter) in the left lumbar region directly below the 12th rib and an exit wound (1 cm. in diameter) through the right midaxillary line in the eighth intercostal space. In its course, the bullet perforated jejunum, ileum, transverse colon, liver, diaphragm and the lower lobe of the right lung, and fractured the right ninth rib. Moderate hemoperitoneum and hemothorax (right) were present.

Case 72.—A Fijian soldier, while standing in the jungle, was mistaken for the enemy and shot by a fellow soldier with a Bren submachinegun at a 30-yard distance. He was wounded at 1500 hours on 1 April 1944. At the 21st Evacuation Hospital, after shock therapy, right lower lobectomy was performed, and a wound in the liver was tamponaded. He died of hemorrhage at 2030 hours on 1 April 1944.

There were two perforating wounds of the right side of the chest. The wounds of entry (each 0.5 cm. in diameter) were both situated in the sixth intercostal spaces 2.5 and 3.7 cm., respectively, from the midline, and the exit wounds were in the eighth intercostal space in the midaxillary line. The ninth rib was fractured. A recent anteriolateral sixth intercostal space incision was present. The lower lobe of the right lung had been removed and the rent in the diaphragm incompletely closed. A large wound occupied the dome of the right lobe of the liver.

Case 73.—A soldier of the 24th Infantry, while lying prone in the jungle on patrol, was struck by Japanese .303 caliber machinegun bullets fired from a distance of 30 yards. At 1000 hours on 19 April, he received shock treatment followed by right thoracotomy. At operation, a bullet and a bone fragment were removed from the right lung, and the diaphragm and lung were sutured. This soldier did not recover from shock and died at 2125 hours on 19 April 1944.

Examination revealed two major wounds. One bullet produced a perforating wound of the right thigh and a compound fracture of the femur. The other bullet penetrated the left buttock and coursed superiorly to terminate in the right side of the pleural cavity. This bullet fractured the fifth lumbar vertebra, severed the cauda equina, lacerated the right kidney, and perforated the diaphragm and lower lobe of the right lung. In addition, there were superficial gutter wounds of the right and left forearms.

Case 74.—A soldier of the 145th Infantry, preparing to climb into a truck, was struck by a fragment of a Japanese mortar shell which burst on the ground 15 yards away. He was wounded at 0730 hours on 18 March 1944. After arriving at the hospital within 1 hour, continuous shock therapy was instituted. Thoracotomy was performed at 0200 on 19 March 1944 in an attempt to arrest hemorrhage.

Examination revealed a sutured wound over the posterior lower left side of the chest 10 cm. in length. A laceration in the lower lobe of the left lung had been sutured. The diaphragm, stomach, and spleen were lacerated. A moderate left hemothorax and hemoperitoneum (2,500 cc.) were present.

Case 75.—A soldier of the 25th Infantry, at 2230 hours on 2 April 1944, left his foxhole to void. On return, he was shot through the abdomen, by an apprehensive bunkmate, with a U.S. .45 caliber revolver from a distance of 2 yards. He died within an hour.

Examination revealed a penetrating wound (1.5 cm. in diameter) in the upper right quadrant of the abdomen. The peritoneal cavity was filled with blood from a perforation of the vena cava. In addition, several loops of jejenum had been perforated.

Case 76.—A soldier of the 145th Infantry, while standing in the open, was struck by fragments of a Japanese 90 mm. mortar shell which burst on the ground 2 yards distant. He was killed instantly on 18 March 1944. Apparently, a fragment had struck the abdominal

wall tangentially in the midline, 0.5 cm. above the symphysis. A loop of ileum was protruding. Only remnants of the urinary bladder remained. The right ilium, right pubic ramus, and sacrum were severely comminuted. The peritoneal cavity contained 2 liters of blood.

Case 77.— A Fijian soldier, while crouching on patrol, was struck in the right lumbar region by a .25 caliber Japanese bullet fired from a distance of 20 yards. He was shot at 1030 hours on 29 March 1944 and died 1 hour later in the aid station from internal hemorrhage.

Examination revealed a perforating wound of the right lumbar region. The entrance wound (0.5 cm. in diameter) was located in the right lumbar region 3 cm. above the posterior superior spine of ilium and the exit wound (0.6 cm. in diameter) on the left buttock on a level with the greater trochanter of the femur. The bullet in its course fractured the wing of the right ilium, severed the right spermatic and pudendal arteries and rectum, and fractured the sacrum. Massive hemoperitoneum was present.

Case 78.—A Medical Department soldier of the 129th Infantry, while lying prone beside his medical officer, was struck by a .25 caliber Japanese bullet fired from the rear at a distance of 75 yards. He spoke a few words, had several convulsive seizures, and died at 1100 hours on 24 March 1944.

Examination revealed a perforating wound of entrance (0.5 cm. in diameter) over the right 12th rib in the posterior axillary line and an exit wound (10 x 0.5 cm.) through the left lumbar region at the level of the fifth spinous process, 15 cm. from the midline. In its oblique course, the bullet fractured the 12th rib, mutilated the right kidney, lacerated the right lobe of the liver and mesenteric border of the midportion of the transverse colon, and fractured the body of the first lumbar vertebra. Massive hemoperitoneum was present.

Case 79.—A soldier of the 25th Infantry left his foxhole at night to defecate. While returning to his hole, he was shot by a fellow soldier with a .30 caliber U.S. machinegun from a distance of 30 yards. He was killed instantly at 1200 hours on 16 April 1944.

One wound had its entrance (0.6 cm. in diameter) over the right scapula and exit (1.2 cm. in diameter) through the left side of the neck. The bullet producing this wound fractured the third cervical vertebra and severed the spinal cord. Another bullet produced a long (32.5 cm.) gutter wound of the right side of the abdomen which resulted in evisceration (fig. 214). This missile pierced the ascending and transverse colon, the ileum, and the liver.

Case 80.—A soldier of the 129th Infantry, while running forward over open terrain, was shot by a .25 caliber Japanese machinegun from a distance of 30 yards. He was killed instantly at 0830 hours on 24 March 1944. Of the two bullet wounds, one (1 cm. in diameter) was classified as penetrating and was situated 7 cm. superior to the umbilicus in the midline; the other was a perforating wound with the entry wound (1 cm. in diameter) through the right lower quadrant and the exit wound (4 x 2 cm.) through the right transverse process of the fourth lumbar vertebra.

Examination of the abdominal cavity revealed a massive hemoperitoneum, severance of the middle colic artery, linear laceration of the midportion of the transverse colon, division of the right common iliac vein and artery, and a compound fracture of the fourth and fifth lumbar vertebras.

Case 81.—A soldier of the 135th Field Artillery, while assigned to a detail burying the Japanese dead in front of the perimeter, wandered away from the main party. He was struck by a .25 caliber bullet which was thought to have been fired by a sniper. He was wounded at 1545 hours on 27 March and arrived at the hospital within 2 hours. Laparotomy was performed, and an extensive wound of the liver was found. He died at 1830 hours on 27 March 1944 of shock from hemorrhage.

Examination revealed a penetrating wound (0.5 cm. in diameter) in the 11th right intercostal space in the anterior axillary line. A recent T-incision was present in the right upper quadrant of the abdomen. The abdominal cavity contained 2 liters of blood. An extensive laceration of the right lobe of the liver had been filled with transplanted muscle. The 12th rib was fractured. Approximately one-third of the shattered right kidney remained, and

FIGURE 214.—Laceration of abdominal wall and evisceration.

bone fragments were found in the remnant of this kidney. There was no wound of exit. No foreign body was recovered.

Case 82.—A soldier of the 182d Infantry, while standing in the open, was struck by multiple fragments of a Japanese hand grenade which exploded 1 yard away. He was wounded at 1345 hours on 13 March 1944. Abdominal exploration which was performed at the clearing station several hours later was reported negative. Multiple penetrating wounds of the left side of the chest wall were debrided at the same time. The patient was evacuated by air from the island on 18 March 1944. Upon arrival at a hospital in the rear echelon on the same day, evisceration was discovered. Secondary wound closure and ileostomy were done. He received penicillin and general supportive treatment but died at 0835 hours on 25 March 1944 of peritonitis. (It is suggested that air evacuation resulted in evisceration.)

Post mortem examination revealed multiple healed wounds involving the left side of the body from the axilla to the knee in a band between the anterior and posterior axillary lines. The abdomen was distended. Incomplete visceral herniation was present below the ileostomy in the partially closed incision. Advanced diffuse suppurative peritonitis was present.

Case 83.—A soldier of the 132d Infantry, while following a jungle trail, was struck by fragments of a 90 mm. Japanese mortar shell which burst on the ground at a 25 yard distance away. He was wounded at 1530 hours on 13 March 1944. Laparotomy was performed at the portable surgical hospital and a rent in the colon sutured. After transfer to the 21st Evacuation Hospital 2 days later, because of severe distension, a colostomy was done. The patient died at 1115 hours on 16 March 1944. Death was attributed to peritonitis.

The wound responsible for death had its entrance at the lower right costal margin and its exit just left of the umbilicus. Diffuse peritonitis resulting from leakage from two perforations in the jejunum which had been missed at the time of operations was discovered. In addition, penetrating wounds of the left and right thigh and the right knee were present.

Case 84.—A soldier of the 129th Infantry, while standing outside his foxhole, was struck by a fragment of a 4.2-inch U.S. mortar shell. The shell fell short and burst on the ground at a 3-yard distance. He was wounded on 27 March 1944. One fragment struck the right hip and coursed retroperitoneally. On 31 March 1944, an ileostomy was performed because of abdominal distention. The patient died on 1 April 1944. Death was attributed to paralytic ileus and unexplained uremia.

The major wound had its entrance (10 x 5 cm.) at the level of the right iliac crest. The fragment producing this wound fractured the ilium and fifth lumbar vertebra, severed the cauda equina, entered the right retroperitoneal space, and shattered the lower pole of the right kidney. A metal fragment was recovered in this area. An ileostomy had been performed through a right paramedian incision. The peritoneal cavity contained a small amount of free serous fluid. All coils of intestine were markedly distended. A large hematoma was present in the right kidney area. A penetrating wound of the right shoulder and a perforating wound through the soft tissues of the right arm were observed.

Case 85.—A soldier of the 25th Infantry, while on patrol, was carrying a grenade in his right hand, when it exploded. He was wounded at 1700 hours on 9 April. Laparotomy was performed at the 31st Portable Surgical Hospital at which time several loops of intestine were resected. On the following day, the patient was transferred to the 21st Evacuation Hospital and died at 2355 hours on 11 April 1944.

Examination revealed five penetrating wounds of the anterior left side of the abdomen, varying from 1.8 to 5 cm. in diameter. The peritoneal cavity contained a moderate amount of sanguinopurulent fluid. End-to-end anastomosis of the upper jejunum and left splenic flexure of the colon had been performed. Early gangrenous changes were noted in the descending colon. Small, multiple lacerations of the spleen, pancreas, and left kidney were present. One grenade fragment was recovered from the splenic fossa, another from the lumen of the transverse colon. Present also was a penetrating wound of the right hand with fracture of the fourth metacarpal and fourth proximal phalanges.

Case 86.—A soldier of the 145th Infantry, while lying in an open foxhole, was struck by a fragment of a 500-pound U.S. aerial bomb, which exploded in a tree 5 yards above. The bomb was dropped accidentally by a U.S. plane leaving on a bombing mission on 19 March 1944. The wound was debrided at the portable hospital shortly thereafter. The soldier was transferred to the evacuation hospital on the following day and died at 0830 hours on 23 March 1944. Death was attributed to peritonitis.

Examination revealed a large penetrating wound (21.4 x 15 x 7.5 cm.) over the crest and wing of the right ilium. This wound was grossly infected. The lamina and spinal process of the fifth lumbar vertebra were destroyed. The retroperitoneal space was filled with purulent exudate. Diffuse fibrinopurulent peritonitis had resulted from direct extension of infection from the wound. A small perforating wound of the right shoulder was clean and granulating.

Case 87.—A Fijian soldier, while on patrol, was struck in the left side of the groin by a .25 caliber Japanese bullet fired from a distance of 25 yards. Though aid reached him immediately, he died in several minutes at 1515 hours on 29 March 1944.

Examination revealed a penetrating wound of the left side of the groin. The wound of entrance (3.1 cm. in diameter) was located 1 cm. below the middle third of the left inguinal ligament. The femoral artery and vein were severed. The markedly deformed rifle bullet was imbedded in the pubis.

Case 88.—A soldier of the 25th Infantry left his foxhole at night to void. On returning, he was mistaken for the enemy and in the resulting confusion was stabbed to death by fellow soldiers. He died within an hour of hemorrhage, on 17 April 1944.

Examination revealed 10 stab wounds in the upper and lower extremities. The right femoral artery was severed in its upper third, and the left radial artery was divided. No other important structures were injured.

Case 89.—A Japanese soldier was brought by American soldiers to the aid post and treated for shock. Despite treatment, he died in several hours.

Examination revealed a perforating bullet wound of the right thigh. The entrance wound (2.5 cm. in diameter) was found on the lateral surface and the exit wound (2.5 cm. in diameter) on the medial aspect. The right femur was shattered in its middle third. Present also was a perforating bullet wound of the abdominal wall in the right lumbar region with wounds of entrance and exit both 2.5 cm. in diameter. This bullet did not enter the peritoneal cavity.

Case 90.—The body of an unknown Japanese soldier was partially decomposed when received for examination. It appeared that the soldier had been wounded by bullets. Death was attributed to shock associated with a severe fracture of the left femur.

Examination revealed a perforating wound of the lower third of the left thigh. The wound of entrance (0.5 cm. in diameter) was medial, and the extensive wound of exit (16.6 x 13.9 cm.) was located on the lateral aspect of the thigh. The lower third of the femur had been shattered, but the great vessels were intact. Present also was a perforating wound of the right buttock.

Case 91.—A soldier of the 132d Infantry, while on patrol lying in an open foxhole, was wounded by the direct burst of a Japanese mortar shell. His right foot was blown away (fig. 215). He was taken to the command post and remained there over night. On the following day, he bled to death while being carried to the rear on a litter. This was a preventable death. The aidman, when questioned, stated that he did not apply a tourniquet before beginning the litter carry because the stump was not bleeding at that time. The soldier was wounded at 1800 hours on 4 April 1944 and died at 1300 hours on 5 April.

Case 92.—A soldier of the 182d Infantry, while on guard beyond the perimeter, tripped the wire to a U.S. boobytrap (grenade). He heard a noise and hit the dirt but was struck on the left buttock by a fragment from a distance of 3 yards. He was wounded in the morning of 29 March 1944. At the clearing station, the wound was debrided and another incision made to remove the fragment. This incision was sutured. Sulfanilamide powder was insufflated into the entrance wound, and it was left open. The patient died at 1100 hours on 4 April 1944 of the gas gangrene which was diagnosed on the same day.

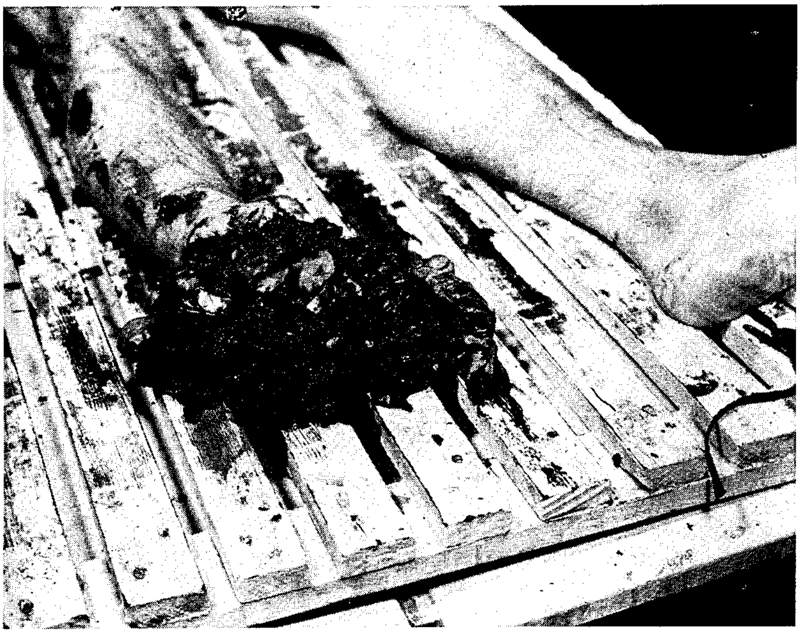


Figure 215—Traumatic amputation stump.

Post mortem examination revealed necrosis and infection of the wound and blood stream infection due to *Clostridium welchii.*

Case 93.—A soldier of the 129th Infantry, while lying prone in the open firing at the enemy, was struck by fragments from a Japanese mortar shell which burst on the ground nearby. He was wounded on 15 March 1944. On the following day, a guillotine amputation was performed through the lower third of the right thigh because of impairment of blood supply. A shattered fourth left toe was removed, and small wounds of the right buttock, lumbar region, right shoulder, and arm were debrided. He was evacuated on 19 March to a station hospital. He developed anuria on 23 March and died at 0845 on 25 March 1944. Death was attributed to uremia and cardiorespiratory failure. The uremia was thought to have been associated with "crush syndrome nephrosis."

At post mortem examination, the various wounds were healing and uninfected.

Case 94.—A soldier of the 148th Infantry, while running along a jungle trail, was struck by fragments of a "short" U.S. 81 mm. mortar shell which exploded between his legs. He was wounded at 0945 on 1 April 1944. At a portable surgical hospital, disarticulation of the left hip was done for an incomplete high traumatic amputation of the left thigh. Whole blood (2,000 cc.) was administered before and during the operation. The patient died of shock 6 hours later.

Examination revealed traumatic amputation of the right leg in the upper one-third, surgical disarticulation of the left hip, and mutilation of the right hand with multiple fractures (fig. 216).

Case 95.—A Japanese soldier was wounded in action on an unknown date. He sustained multiple penetrating wounds of the right lower extremity and a superficial wound of the scalp from fragments of a U.S. landmine. He was treated at the 21st Evacuation Hospital, developed gas gangrene of the right leg, and died at 1530 hours on 12 March 1944.

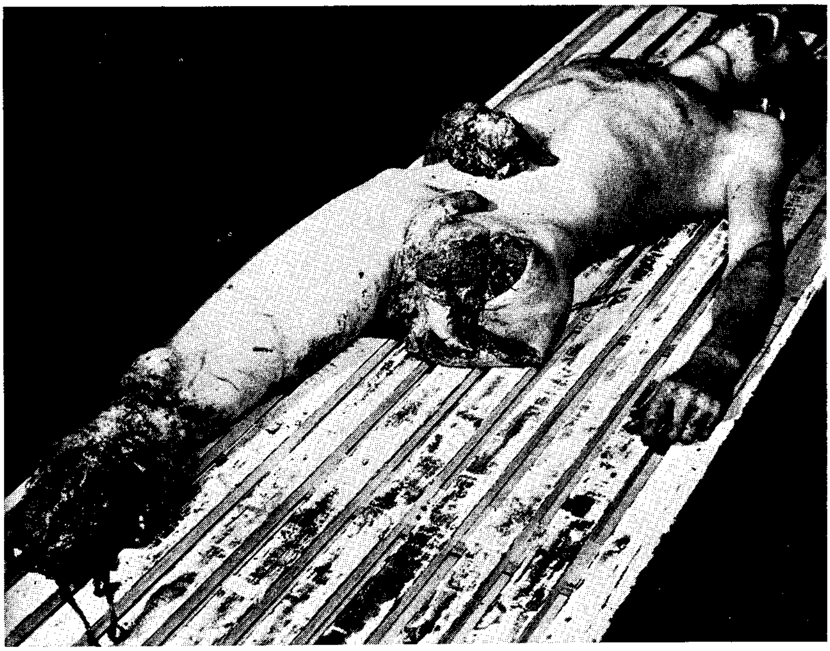


FIGURE 216.—Multiple mutilating wounds and traumatic amputations.

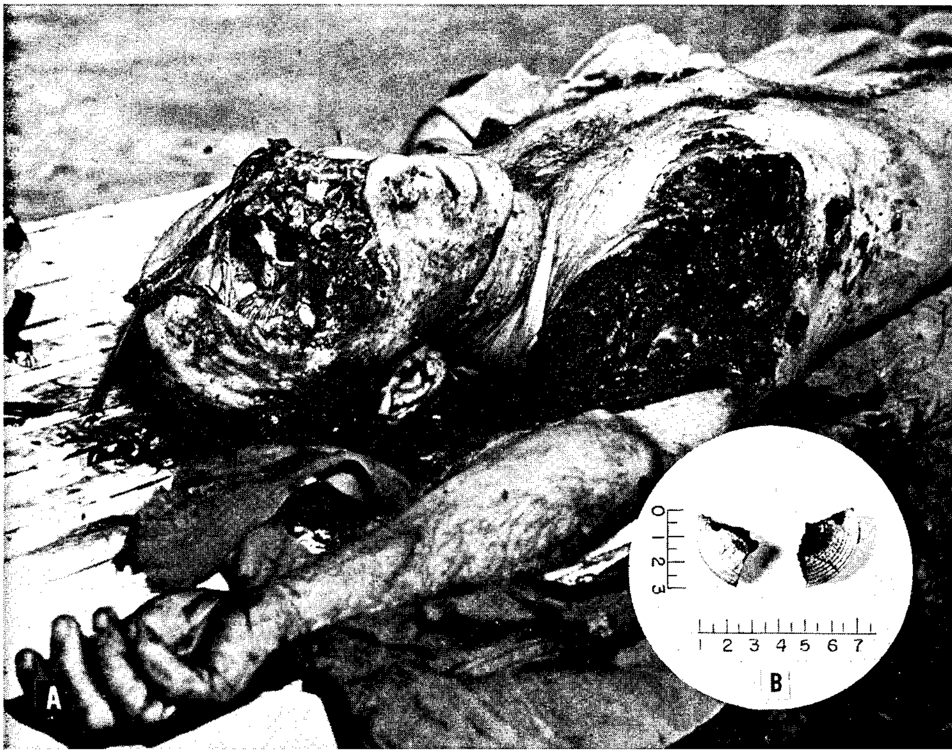


FIGURE 217.—A. Multiple wounds produced by U.S. landmine. B. Recovered fragments of U.S. landmine.

Examination revealed the characteristic odor and edematous discoloration of gas infection. The right tibia and fibula were fractured in the middle third. The largest of the penetrating wounds measured 2.5 centimeters.

Case 96.—A Japanese soldier was wounded in action on 24 March and died at 2000 hours on 28 March 1944. Death was caused by gas gangrene of the left thigh.

Examination revealed a large wound (17 x 16.2 cm.) involving the medial surface of the thigh. The wound apparently had been caused by an HE shell fragment. The femoral vessels were intact but thrombosed. The femur was intact. The wound exhibited characteristic features of gas bacillus infection.

Case 97.—A soldier of the 129th Infantry, while walking beyond the perimeter hunting for souvenirs, stepped on a U.S. landmine and was killed instantly on 30 March 1944.

Examination revealed multiple wounds of the head, chest, and abdomen (fig. 217). One missile destroyed the antral, orbital, and frontal areas of the skull. Only remnants of brain tissue remained. Another fragment entering the right side of the thorax had resulted in perforation of the right ventricle and almost total destruction of the right lung. Two fragments were recovered (fig. 217B), one from the pericardial sac and the other from the pleural cavity. A fragment penetrating the abdominal cavity had completely severed the right lobe of the liver.

Case 98.—This soldier was one of four men assigned to a pillbox. Thinking they were being surrounded by Japanese, the soldiers became alarmed and left the box and separated to seek other cover. Three of the men took cover in another foxhole. After a time, the

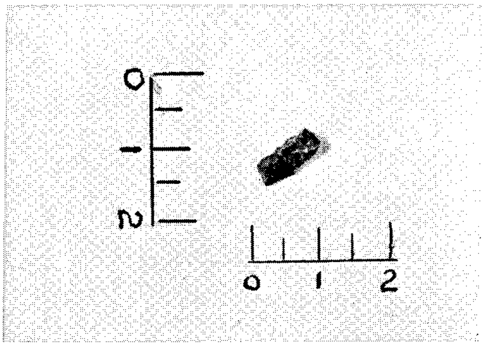


FIGURE 218.—Small mortar shell fragment recovered from brain.

fourth man came to join them. He was met with rifle fire and hand grenades from his apprehensive companions as he walked down the trench to enter the hold. He was killed instantly at 2130 hours on 20 April 1944.

Examination revealed seven wounds of the chest, scalp, back, and lower extremities. These wounds were all produced by grenade fragments; no bullet wounds were found. Instantaneous death resulted from the thoracic injury. One fragment traversed the left supraclavicular fossa and the posterior first right intercostal space. The entrance wound was 2.5 cm. in diameter. This missile fractured the first rib, lacerated the upper lobe of the left lung, and, in crossing the midline, fractured the bodies of the fourth, fifth, sixth, and seventh dorsal vertebras. Massive hemothorax was found. Bilateral fractures of the tibia and fibula and fracture of the left femur were present.

Case 99.—A soldier of the 131st Engineer Combat Battalion left his foxhole to rescue a friend who had been wounded. While running, he was struck by fragments of a Japanese 90 mm. mortar shell which burst on the ground 2 yards away. He died in the hospital several hours later at 0830 hours on 24 March 1944.

Examination revealed penetrating wounds of the left parietal and right kidney regions. The wound of entrance (1.5 cm. in diameter) in the left parietal region was filled with brain tissue. Stellate fracture lines coursed the cranial vault. The parietal lobe was lacerated, and intracranial hemorrhage was marked. A small fragment of metal was removed from the brain tissue (fig. 218). Another fragment pierced the 12th rib right to enter the abdominal cavity, fragmented the right kidney, and lacerated the right lobe of the liver. Massive hemoperitoneum was present.

Case 100.—A Fijian commando, while on patrol, stepped on a U.S. landmine. He was killed instantly at 1300 hours on 26 March 1944.

Examination revealed seven wounds (fig. 219A). A fragment entering the head produced an entrance wound (1.2 cm. in diameter) through the right frontotemporal region. In its course, this fragment fractured the maxilla, zygoma, the frontal and temporal bones, and destroyed the right frontal lobe of the brain. A penetrating wound (2 cm. in diameter) of the abdomen was located 6 cm. above the umbilicus. The fragment producing this wound severed or perforated the pylorus, duodenum, jejunum, and mesentery of the small bowel and was found lodged in the soft tissue at the aortic bifurcation. The peritoneal cavity was filled with blood. Another missile which produced a penetrating wound (2.2 cm. in diameter) in the left pectoral region severed the brachial plexus. This fragment was found in the subcutaneous tissue over the sixth rib in the posterior axillary line. In addition, 2 penetrating wounds of the chest wall, 1 of the abdominal wall, and 1 of the left thigh were discovered. Figure 219B shows the metal fragments recovered from the chest wall and peritoneal cavity.

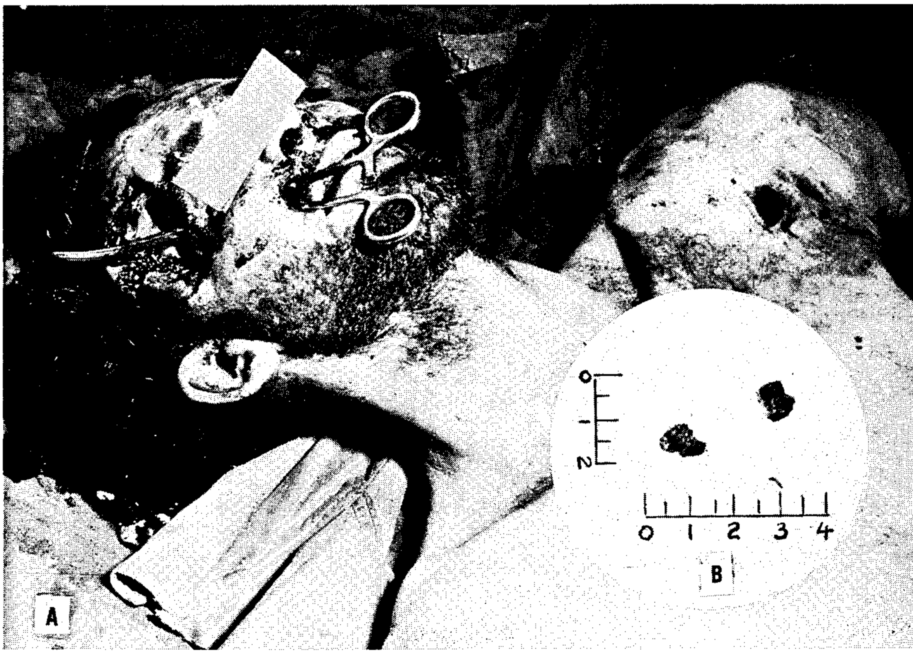


FIGURE 219.—A. Wounds of head and chest produced by U.S. landmine. B. Recovered fragments from chest wall and peritoneal cavity.

Case 101.—A soldier of the 164th Infantry, while crouching and advancing on patrol, was struck by several .25 caliber Japanese bullets fired by a sniper from a distance of 50 to 75 yards. The soldier was killed instantly at 1620 hours on 29 March 1944.

Examination revealed six perforating wounds. The thorax was perforated by a bullet entering posteriorly. The entrance wound (1.5 cm. in diameter) was found in the left third intercostal space at the costovertebral junction and the exit wound (6.2 cm.) over the right deltoid prominence. In its course, this missile fractured the third rib, perforated the upper lobes of the left and right lungs, and fractured the right clavicle and scapula. Massive bilateral hemothorax resulted.

The entrance wound (2.5 cm. in diameter) in the abdominal wall was situated in the left lower quadrant and the exit wound (5 cm. in diameter) on the right side of the scrotum (fig. 220). The missile producing these wounds lacerated the sigmoid colon, fractured the symphysis pubis, and avulsed the right testicle. The left femur was fractured in its lower third by a bullet which produced an oblique perforating wound. This bullet traversed the thigh from the lateral aspect of the upper third to the medial aspect of the lower third. In addition, perforating wounds of the left buttock, left shoulder, and left ear were present.

Case 102.—A U.S. soldier, while in front of the perimeter cutting down trees to improve line of fire, stepped on a U.S. landmine and was killed instantly at 1015 hours on 1 April 1944.

Examination revealed 18 widely distributed wounds. The head wound was obviously responsible for immediate death. The fragment which produced the extensive head wound (10 x 5 cm.) destroyed the right orbit and right frontal bone and avulsed both frontal lobes and part of the right parietal lobe of the brain. In addition, there were numerous penetrating and perforating wounds of the upper and lower extremities and abdominal and chest walls. The following compound fractures were found: Right tibia, left tibia and fibula, right femur, right ulna, and mandible.

Figure 221 shows the recovered landmine fragments.

FIGURE 220.—Perforating wound of abdomen, with catheter in place.

Case 103.—A soldier of the 140th Field Artillery Battalion, while walking through thick jungle on patrol, was shot by .25 caliber Japanese bullets fired from a distance of 10 yards. He was wounded at 1600 hours on 14 March 1944 and reached the hospital 1 hour later. The wounds sustained necessitated multiple operations. The severed left axillary vein was ligated and the wound left open. Exploratory cystotomy revealed no perforation of the urinary bladder making suprapubic drainage unnecessary. Compound comminuted fractures of the right femur and ilium were accompanied by extensive wounds of soft tissue about the right hip joint and buttocks. These wounds were debrided. The patient died at 1450 hours on 16 March 1944. His death was attributed to gas gangrene and peritonitis.

Examination revealed a foul, edematous, discolored crepitant wound of the right hip. A sinus track containing a serosanginous exudate led to the fractured head and neck of the femur. The edema and discoloration extended above to the wound into the right buttock. An operative incision was present in the low midline. The terminal ilium was gangrenous as a result of an unexplained thrombosis of the mesenteric vessels. Gangrene of the ilium accounted for the presence of a diffuse seropurulent peritonitis.

Case 104.—A soldier of the 132d Infantry stepped on a mine while on an authorized mission in front of the perimeter arming U.S. landmines at 0830 hours on 27 March 1944. He was taken immediately to the clearing station. There his numerous wounds, including the wound of a traumatic amputation of the left foot, were debrided. He died of shock at 1445 hours on 27 March 1944.

Examination revealed 13 wounds. The four wounds of the left lower extremity were the wound of an amputation stump in the lower third of the leg, a linear wound (12.5 x 6.2 cm.) over the knee accompanying a compound comminuted fracture of the patella, an irregular wound 10 cm. in length on the medial aspect of the knee, and a superficial wound on the medial surface of the thigh. Three wounds of the right leg were seen: A gutter wound 7.5 cm. long on the dorsum of the foot, a small penetrating wound of the ankle accompanying a fracture of the internal malleolus, and a superficial wound of the calf. A large wound

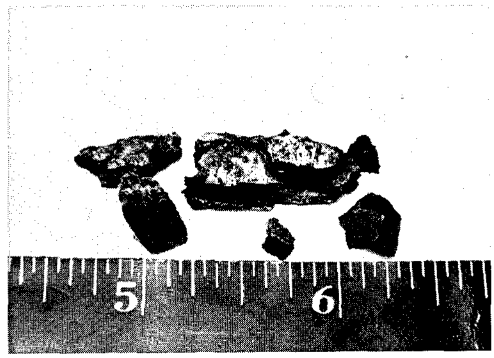


FIGURE 221.—Recovered fragments of U.S. landmine.

(12.5 x 7.5 cm.) of the right buttock was associated with a compound fracture of the sacrum. Present also was a compound comminuted fracture of the right ulna. In addition, wounds of the back (2), right forearm (2), and left buttock (1) were found.

CIRCUMSTANCES AND PROTECTIVE MEASURES

A study of the circumstances under which wounds occur may yield information regarding the effectiveness of weapons under battle conditions, the results of training, and the need for protective measures. Wounds occur under a variety of conditions which make classification difficult. However, an attempt was made to determine the position and occupation of the soldier when wounded, the type of cover, and the distance from the shellburst or weapon. This information was obtained from the wounded man or from his comrades or from both. The circumstances under which the soldier was wounded usually could be obtained in considerable detail. However, the caliber and exact type of weapon frequently could not be identified other than as belonging to the general classification of weapons, such as rifle, machinegun, and mortar.

Influence of Position and Cover on Number of Casualties

When the subject of "cover" is viewed broadly, casualties fall naturally into three general groups depending upon the relative degree of protection available at the time of wounding. In the first group are placed those who had the best protection, usually a well-constructed pillbox covered by fairly heavy logs. In the second group are those who had no overhead cover but were protected on all sides by well dug-in holes or trenches. The third group comprised those with the least protection and was subdivided into those who had no protection whatsoever and those who had partial protection. A soldier in a shallow foxhole or behind a tree or log would be considered one with partial protection. There were 81 casualties produced by miscellaneous weapons; however, their positions at the time of wounding were not considered significant.

These 81 casualties are excluded from the present discussion but will be discussed later in this chapter. In 150 instances, the position was not stated, therefore data regarding "protection and position" were available in 1,557 cases and are summarized in table 100.

TABLE 100.—*Distribution of 1,557 casualties by causative agent and by position and protection*

Position and protection	Causative agent					Total casualties	
	Rifle	Machine-gun	Grenade	Mortar	Artillery	Number	Percent
Standing:							
No cover	184	57	49	189	88	567	36. 4
Partial cover	4	1	1	5	2	13	. 8
Total	188	58	50	194	90	580	37. 2
Sitting:							
No cover	92	25	39	114	15	285	18. 3
Partial cover	10	0	1	15	2	28	1. 8
Total	102	25	40	129	17	313	20. 1
Prone:							
No cover	72	30	62	122	26	312	20. 0
Partial cover	13	3	5	12	2	35	2. 3
Total	85	33	67	134	28	347	22. 3
Pillbox	11	6	33	64	26	140	9. 0
Trench hole	29	12	19	91	26	177	11. 4
Total	40	18	52	155	52	317	20. 4
Grand total	415	134	209	612	187	1, 557	100. 0

Those who were erect, standing, walking, or running were included under the classification "Standing." Those who had considerably less body area exposed, whether they were sitting or crouching or kneeling, were placed in the group designated "Sitting." The term "prone" does not require explanation. Among the 1,557 cases, the weapons were distributed as follows: Mortar, 39.3 percent; rifle, 26.6 percent; grenade, 13.4 percent; artillery, 12.0 percent; and machinegun, 8.7 percent.

It is obvious that the body surface exposed depends upon the position of the soldier when wounded and should bear some correlation with the number of hits. It is important to know whether the number of hits depends solely upon the body surface exposed or whether it is greater for aimed weapons. Data relating to this problem were obtained by examining the least protected

group (standing, sitting, and prone) which constituted 1,240 (79.9 percent) of the total 1,557 casualties.

By reference to table 101, it is apparent that there are approximately twice as many casualties among the standing as there are among either the sitting or the prone. Furthermore, the number of casualties is approximately equally divided between the two latter groups. When the factor of partial cover is excluded by omitting the small number (76 casualties) who had slight protection, the relative proportion of casualties in the three subdivisions remains unchanged (table 102). This is what might be expected were all missiles unaimed and traveling at random. In this event, the number of wounds received would be in approximate proportion to the projected body area exposed. On the basis of the foregoing finding, it appears that, in this particular jungle campaign, the number of casualties depended upon random unaimed hits which were roughly in proportion to the body area exposed (table 70).

In the total group (1,557), 317 or 20.1 percent (table 100) were wounded in well-covered pillboxes or well dug in but uncovered holes or trenches. These

TABLE 101.—*Distribution of 1,240 casualties, by aimed and random fire and by position (with and without cover)*

Position	Aimed fire [1]		Random fire [2]		Casualties	
	Number	Percent	Number	Percent	Number	Percent
Standing	246	50. 1	334	44. 6	580	46. 8
Sitting	127	25. 9	186	24. 8	313	25. 2
Prone	118	24. 0	229	30. 6	347	28. 0
Total	491	100. 0	749	100. 0	1, 240	100. 0

[1] Rifle and machinegun.
[2] Mortar, artillery, and grenade.

TABLE 102.—*Distribution of 1,164 casualties, by aimed and random fire and by position (no cover)*

Position	Aimed fire [1]		Random fire [2]		Casualties	
	Number	Percent	Number	Percent	Number	Percent
Standing	241	52. 4	326	46. 3	567	48. 7
Sitting	117	25. 4	168	23. 9	285	24. 5
Prone	102	22. 2	210	29. 8	312	26. 8
Total	460	100. 0	704	100. 0	1, 164	100. 0

[1] Rifle and machinegun.
[2] Mortar, artillery, and grenade.

casualties were nearly equally divided between the pillbox (44.8 percent) and the open trench (55.2 percent). In this relatively well protected group, 259 (81.7 percent) were wounded by random fire and 58 (18.3 percent) were wounded by aimed fire. Among the casualties produced by aimed weapons, 70.7 percent were in the open trench but only 29.3 percent in the pillbox. Casualties from random fire were approximately equally distributed between the pillbox (48.1 percent) and the open trench (51.9 percent). One may, therefore, conclude that the covered pillbox offers relatively greater protection against aimed weapons.

Type of Action

Among the total casualties, there were 1,620 cases in which information was available concerning the type of action in which the men were involved. The number wounded on patrol or in defensive and offensive action is shown in table 103.

Range of Small Arms or Distance From Burst

The approximate range was known in 339 casualties resulting from rifle fire and in 121 casualties resulting from machinegun fire. In table 104, this group is tabulated in percentages according to range and disposition of casualties. The higher lethal effect of bullets at close range should be noted. At longer range (over 75 yards), it would appear that the casualties received either minor or nonvital wounds since none received wounds of sufficient severity to cause evacuation to the United States. The distance from the weapon or shellburst was estimated in most instances and is, therefore, open to considerable error. It is likely that the actual distance from a shellburst was greater than the estimated distance. In future studies, suitable samples might be used to check on this error. Furthermore, indoctrination of troops, before combat, regarding the importance of such data might lead to more accurate observation.

Approximate distances from shellbursts (including knee mortars) were known in 623 casualties produced by mortar shell fragments (including knee mortars) and in 176 caused by artillery shell fragments. The percentage distribution of these casualties according to the disposition of the patient is shown in table 105. In the jungle, the effect of a shellburst should be more limited than in open terrain. Approximately 60 percent of the casualties were under 10 yards from the burst.

Similar results are tabulated for the grenade in table 106. It is rather surprising to find that the effectiveness of the Japanese hand grenade extends beyond 5 yards, as evidenced by the fact that 25.1 percent were wounded at this distance. However, it is possible that some of these casualties were produced by U.S. grenades.

TABLE 103.—*Distribution of 1,620 casualties, by aimed and random fire of causative agent and by type of action*

Type of action	Aimed fire		Total casualties (aimed fire)		Random fire			Total casualties (random fire)		Total casualties (combined fire)	
	Rifle	Machine-gun	Number	Percent	Mortar	Artillery	Grenade	Number	Percent	Number	Percent
	Number	*Number*			*Number*	*Number*	*Number*				
Patrol	105	34	139	24. 6 (61. 0)	35	29	25	89	8. 4 (39. 0)	228	14. 1
Defensive	253	78	331	58. 7 (27. 4)	588	136	152	876	83. 0 (72. 6)	1, 207	74. 5
Offensive	58	36	94	16. 7 (50. 8)	50	3	38	91	8. 6 (49. 2)	185	11. 4
Total	416	148	564	100. 0 (34. 8)	673	168	215	1, 056	100. 0 (65. 2)	1, 620	100. 0

NOTE.—Figures in parentheses express percent aimed and random fire of totals of combined fire. A higher percentage were wounded on both patrol and offensive action by aimed fire. On defensive action, the majority were wounded by random fire.

TABLE 104.—*Distribution of 460 casualties produced by small arms weapons, by range of fire and disposition*

[Values expressed as percentages according to type of weapons]

Weapon and range (yards) of fire	Dead	Living wounded		Total average
		Returned to duty	Evacuated to United States	
Rifle:				
0 to 25	54.7	17.9	37.7	33.9
25 to 50	27.3	8.3	19.4	16.8
50 to 75	8.6	37.2	42.9	29.5
Over 75	9.4	36.6	.0	19.8
Total	100.0	100.0	100.0	100.0
Machinegun:				
0 to 25	40.3	3.2	28.6	28.1
25 to 50	45.1	6.5	35.7	33.1
50 to 75	6.5	51.6	35.7	24.8
Over 75	8.1	38.7	.0	14.0
Total	100.0	100.0	100.0	100.0

TABLE 105.—*Distribution of 799 casualties produced by shell fragments, by distance from point of burst and disposition*

[Values expressed as percentages according to type of shell fragments]

Shell fragment and distance (yards) from point of burst	Dead	Living wounded		Total average
		Returned to duty	Evacuated to United States	
Mortar:				
0 to 10	79.4	64.5	66.6	66.7
10 to 20	8.2	19.1	22.0	18.3
20 to 50	11.0	12.1	7.6	11.2
Over 50	1.4	4.3	3.8	3.8
Total	100.0	100.0	100.0	100.0
Artillery:				
0 to 10	86.0	50.5	53.8	59.6
10 to 20	9.3	21.5	19.2	18.2
20 to 50	4.7	15.9	16.6	12.9
Over 50	.0	12.1	15.4	9.7
Total	100.0	100.0	100.0	100.0

TABLE 106.—*Distribution of casualties wounded by hand grenade fragments, by distance from point of burst*

[Values expressed as percentages according to weapon]

Distance from point of burst	Dead	Living wounded		Total average
		Returned to duty	Evacuated to United States	
Yards:				
0 to 3	100. 0	67. 3	56. 7	67. 6
3 to 5	. 0	6. 4	13. 6	7. 3
Over 5	. 0	26. 3	29. 7	25. 1
Total	100. 0	100. 0	100. 0	100. 0

Time Phase

In table 107, casualties are separated according to the period of time in which they occurred. The first phase extends to the beginning of the Battle of the Perimeter, 15 February to 7 March; the second phase covers the intensive period of perimeter activity of 8 March to 28 March; and the last phase, the subsequent relatively inactive period of 29 March to 21 April 1944. Eighty percent of the casualties occurred during the Battle of the Perimeter.

Miscellaneous Weapons and Circumstances

A total of 81 casualties (4.5 percent of 1,788) resulted from the following miscellaneous weapons: Landmine (excluding grenade boobytraps), 34; aerial bomb, 15; .45 caliber pistol, 14; powder explosions and flares, 6; bangalore torpedoes, 9; bazooka, 2; and bayonet, 1. Enumeration of the very varied circumstances surrounding the wounding of these patients serves no purpose since no general conclusion can be derived.

In jungle warfare, a fair number of casualties result from the overhead explosion of mortar or artillery shells, or aerial bombs overhead, as a result of detonation on impact with a tree or its branches. Such explosions are designated "tree bursts" as distinguished from "ground bursts." In 900 instances, there were 93 (11.5 percent) tree bursts. Mortar shells constituted 58.1 percent of all tree bursts; artillery shells, 34.4 percent; and aerial bombs, 7.5 percent. Ground bursts were divided as follows: Mortar shells, 79.1 percent; artillery shells, 20.0 percent; and aerial bombs, 0.9 percent.

TABLE 107.—*Distribution of 1,707 casualties, by aimed and random fire of causative agent, during survey period (15 Feb.–21 Apr. 1944)*

Period	Aimed fire		Total casualties		Random fire			Total casualties		Total casualties (combined fire)	
	Rifle	Machinegun	Number	Percent	Mortar	Artillery	Grenade	Number	Percent	Number	Percent
1944											
First phase (15 Feb.–7 Mar.)	35	7	42	7.0	39	35	11	85	7.7	127	7.4
Second phase (8 Mar.–28 Mar.)	308	111	419	70.2	622	140	184	946	85.2	1,365	80.0
Third phase (29 Mar.–21 Apr.)	102	34	136	22.8	32	18	29	79	7.1	215	12.6
Total	445	152	597	100.0 (35.0)	693	193	224	1,110	100.0 (65.0)	1,707	100.0

NOTE.—Figures in parentheses represent percentages of aimed and random fire of total combined fire.

Protective Measures and Recommendations

Pillboxes.—Opinion has been expressed that the large size of the firing slit resulted in casualties which might have been avoided by a smaller opening. In some instances, nearby tree snipers were able to direct fire through the firing slit. Because of this fact, it has been suggested that an eave overhanging the firing slit might be a useful additional means of protection. The findings of the survey team indicate that gunfire directed through the slit is of little importance. Wounding through the firing slit did occur in 104 (6.7 percent) instances in 1,557 casualties. However, in this group, the aimed weapons (rifle and machinegun) were responsible for only 9 (8.6 percent) of those so wounded. In view of this small number, the advisability of the overhanging eave is doubtful. However, a considerable number of casualties (95) were caused by shell fragments passing through the firing slit. This would indicate the need for keeping the size of the firing slit as small as is consistent with observation and maneuverability of weapons within the pillbox (fig. 222).

Protection against the hand grenade was afforded by the use of wire (chicken) net (fig. 223) at night to cover peepslit openings and was favorably recommended. Some type of rubber net might serve to "bounce off" the unexpected grenade even better than the wire net. The earth should be sloped from the slit opening so that grenades will roll away.

The construction of pillboxes might be improved by the use of heavier (12 inch) logs. Hardwood is recommended if obtainable as termites destroy

U.S. Army photo

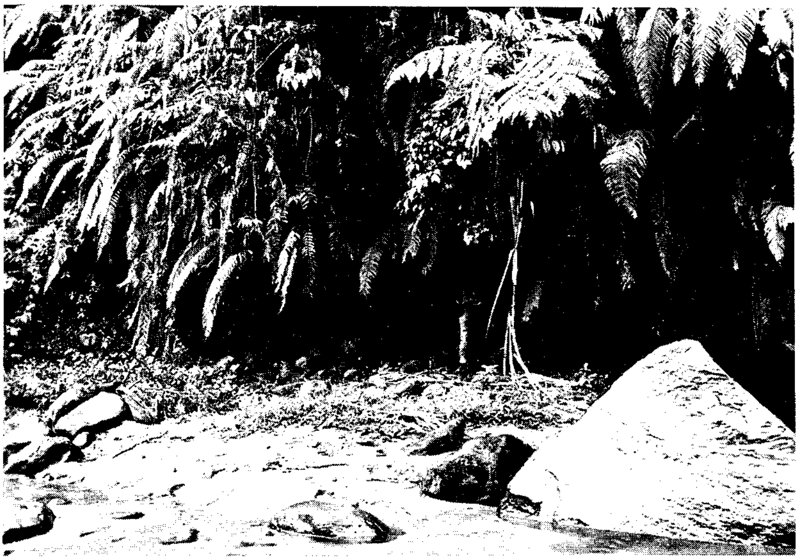
FIGURE 222.—Well-constructed pillbox showing size of firing slit.

FIGURE 223.—Wire netting covering firing slits. This netting was used successfully to "bounce off" enemy grenades.

soft timber quickly. Some concrete could be used to advantage. Since the location of the pillbox is usually known to the enemy, camouflage should be sacrificed for sturdy construction. The earth floor in a square log pillbox should not be excavated out to the edges of the logs. On the contrary, a stronger pillbox results if the central excavation is made circular in shape, thus leaving more earth in the corners.

Combat training.—The majority of the experienced combat personnel expressed the opinion that the Japanese soldier made better use of cover than did Allied troops and were better trained at "digging in" quickly. They utilized all natural cover (fig. 224). They crawled close to the ground, and their foxholes were small, efficient, and well suited to the purpose intended. On the contrary, Allied troops were frequently careless in exposing themselves unnecessarily (fig. 225) and ofttimes were content with foxholes which were entirely too shallow (fig. 226). Many wounds were received because soldiers crawled with buttocks elevated, making a large silhouette. In training and staging areas, more time devoted to digging in would serve not only to stress the importance of adequate cover but would also develop the necessary muscle.

When under fire, the importance of dispersion (figs. 227 and 228) should be emphasized. For example, in one instance, 13 men preparing to enter a truck were killed or wounded by a single shell. Neglect of this principle by enemy troops resulted in 600 enemy killed by Allied artillery fire in one area.



U.S. Army photo

FIGURE 224.—Natural jungle growth which provided excellent camouflage.

Medical suggestions.—Aidmen should receive more preliminary training in vena puncture. Lack of familiarity and practice in this technique frequently delayed the administration of plasma. Since patients cannot be evacuated at night from frontline positions, every soldier should know the principles of first aid. Under combat conditions similar to those at Bougainville, it is felt that the oral administration of sulfanilamide medication should be discontinued in the field unless on patrol far from medical installations. It was often difficult to know later in the hospital whether a man had received this medication and, if so, in what amounts. It was estimated that less than 10 percent took the drug by mouth after having been wounded. This uncertainty as to dose frequently delayed adequate sulfonamide therapy. Finally, the practice of sending aidmen forward to remove the dead under fire is very demoralizing and should be condemned.

Body armor.—The subject of protection would not be complete without some expression of opinion regarding the advisability of body armor. Many line officers believe that under certain tactical situations the judicious employment of some type of body armor would be definitely advantageous. Its routine use is not recommended. The objections most frequently raised are that the infantry foot soldier is already burdened with a maximum amount of weight, that any further equipment would be cumbersome and would interfere with fighting efficiency, and, finally, that too much protection induces an "oyster complex." These objections could be overcome if the use of armor were restricted to a special circumstance. When the tactical situation demanded body armor, it could be transported to that point, issued, and later

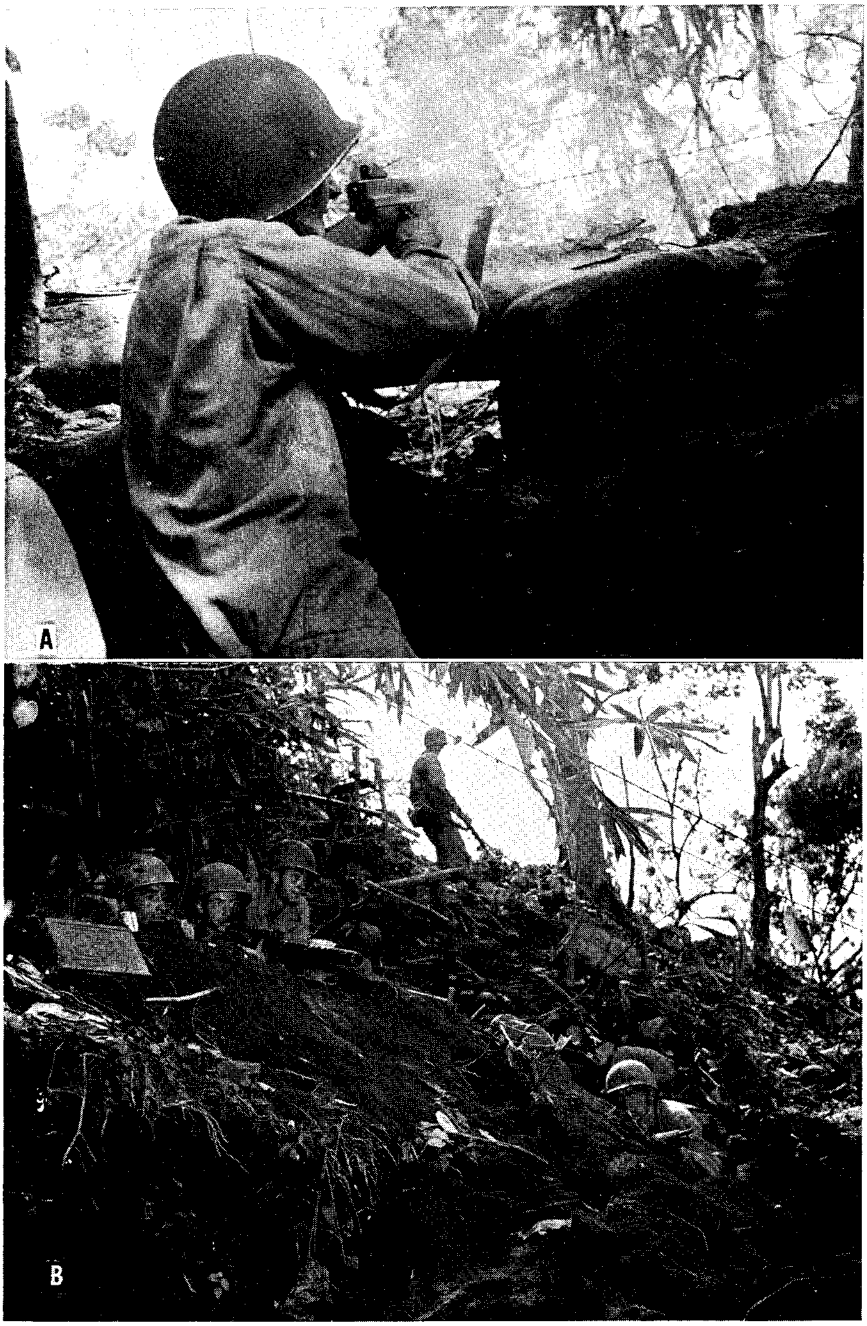


FIGURE 225.—"Necessary" and "unnecessary" exposure. A. Necessary exposure of head and upper extremities. B. Necessary and unnecessary exposure in a position on Hill 700.

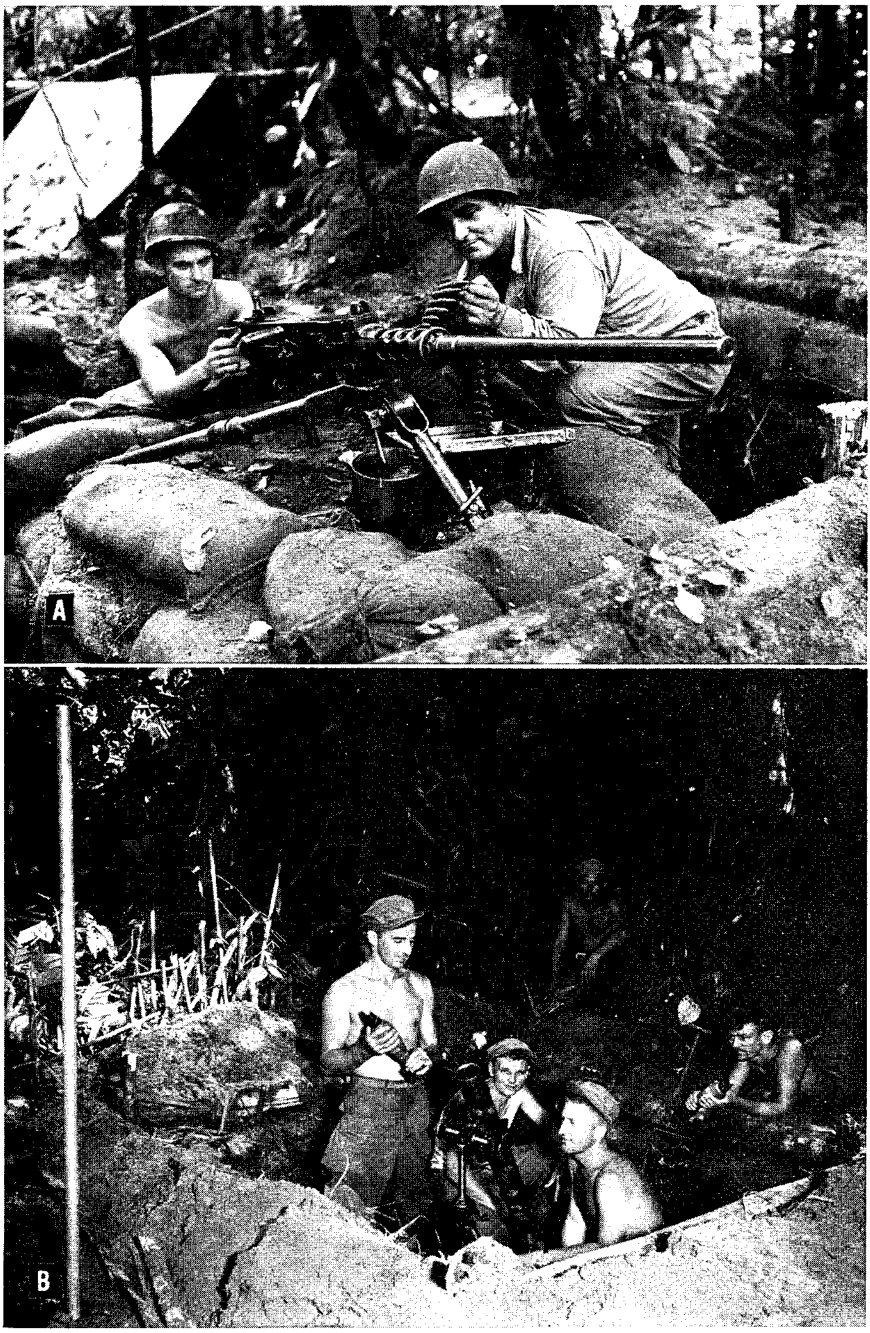


FIGURE 226.—"Little" and "moderate" protection. A. Machinegun emplacement with little protection. B. Shallow 81 mm. mortar emplacement with moderate protection.

FIGURE 227.—Unnecessary exposure and concentration of men.

FIGURE 228.—Infantry advancing behind tanks. Many casualties occurred when the Japanese withheld fire until the tanks had passed.

collected when the objective had been attained. In the type of combat at Bougainville, the soldier did not carry a full pack, and for brief intervals all unessential equipment could have been discarded in favor of armor.

SUMMARY

The primary purpose of this report was to evaluate the relative effectiveness of the different weapons as casualty-producing agents. In order to achieve this aim, it was necessary to determine and to correlate the varied circumstances surrounding wound production in each individual case. It was essential to know what weapon caused the wound, the anatomic region wounded, the range and distance from the burst, the available protection, the degree of disability, the treatment and disposition of the patient, and all details relating to death. This report comprises a study of all battle casualties (living and dead) occurring in the U.S. Army ground forces on Bougainville Island from 15 February to 21 April 1944.

The Bougainville campaign possessed certain features which are not ordinarily found in jungle warfare. A beachhead was made in virgin jungle for the purpose of establishing airfields. Not until 4 months later did the enemy engage in the major large scale attack referred to as the "Battle of the Perimeter." During this interval, the perimeter was extended and strongly fortified, and an excellent system of roads was constructed within the defended area. When the enemy attack came, the Allied force was superior both in numbers and in equipment. They had gained control of the air and in addition had the advantage of overwhelming artillery superiority. Ample vehicular transportation and smooth all-weather roads facilitated supply and evacuation. Medical installations had been completed which were easily accessible and adequate to meet all exigencies. Consequently, a high standard of medical care was maintained. The Japanese on the contrary were handicapped by the necessity of taking offensive action against a well-established perimeter defended by a greater number of better equipped troops. Furthermore, their supply problem was very difficult. They were compelled to transport supplies chiefly by pack through dense jungle and over narrow, rugged mountain trails. However, with the exception of artillery weapons and shells, the enemy by dogged effort was able to keep adequate supply of arms and ammunition.

The U.S. forces at Bougainville sustained 2,335 casualties from 15 February to 21 April 1944. Of these, 16.9 percent died; 69.5 percent were returned to duty; and 13.6 percent were evacuated to the United States. In the total group, there were 547 who were so lightly wounded that they were returned directly to duty from the battalion aid stations or collecting stations. Since the effect of weapons on this group was minimal and since these soldiers were not actually lost to combat, they were excluded from the remainder of the study. Therefore, all subsequent percentage figures were based on

1,788 battle casualties who were admitted to hospitals or were killed in action. Using the 1,788 casualties as a basis, it was found that approximately 1 battle death (KIA and DOW) occurred among every 4.5 casualties, making a mortality of 22.1 percent. The living wounded numbered 1,393; of these, 77.2 percent were returned to duty and 22.8 percent were evacuated to the United States.

The majority of casualties (78.8 percent) occurred during the Battle of the Perimeter, a period arbitrarily defined as extending from 8 to 28 March 1944. Most of these casualties occurred within U.S. lines. Because of the fortuitous circumstances of hospital accessibility, these wounded obtained adequate medical care, usually within 1 hour and in most instances in much less time. Patrol activity was chiefly responsible for the small number of casualties which occurred before and after this battle. These casualties constituted the major problem in the evacuation of the wounded. During the Battle of the Perimeter, the American loss was 210 killed in action as contrasted to 8,527 Japanese dead, a ratio of 1 : 24.6.

Anatomic distribution of wounds.—A striking contrast is observed in the percentage distribution (regional frequency) of wounds in the dead, in the living, and in both groups combined, when classified according to the anatomic region involved (table 108).

Wound distribution.—It was found that the distribution of wounds was dependent largely upon exposure to the random missile and not upon directed fire. This was demonstrated clearly by comparing the actual with the expected number of hits in each anatomic region. This was done by superimposing the percentage of hits over the percentage mean of the projected body area. In this way, the directed fire (rifle) was compared to the undirected fire (mortar) and to the total hits by all weapons. A close correlation exists between the expected number of hits and the mean projected body area except in the case of a single region, the head. In the head, the number of hits exceeded the expectancy by more than 100 percent. This would indicate that in combat

TABLE 108.—*Percentage distribution (regional frequency) of wounds in 1,788 casualties (395 dead, 1,393 living wounded), by anatomic location and order of frequency*

Order of frequency	Total casualties		Dead		Living wounded	
	Anatomic location	Regional frequency	Anatomic location	Regional frequency	Anatomic location	Regional frequency
1	Lower extremity	22. 7	Head	36. 5	Lower extremity	28. 2
2	Head	21. 5	Multiple	25. 6	Upper extremity	22. 9
3	Multiple	18. 6	Thorax	22. 0	Head	17. 2
4	Upper extremity	17. 9	Abdomen	12. 1	Multiple	16. 6
5	Thorax	12. 9	Lower extremity	3. 5	Thorax	10. 3
6	Abdomen	6. 4	Upper extremity	. 3	Abdomen	4. 8

exposure of the head exceeds that of any other anatomic region. However, the fact that percentage of rifle hits exceeded the percentage of unaimed mortar hits by a perceptible margin would tend to indicate that the factor of marksmanship does account for a moderate number of head wounds.

Effectiveness of weapons.—In table 109, the number of battle casualties produced by the different weapons is shown in relation to the relative lethal effect of each weapon. A clear distinction exists. The total number of casualties produced by a given weapon reflects not only the extent of its use by the enemy but also the effectiveness of that weapon when employed under the particular circumstances of that battle. On the other hand, the relative lethal effect of a weapon is defined as the percentage killed by all hits and is a measure of the effectiveness of that weapon under all conditions (providing facilities for medical care are comparable and constant). For example, though the mortar produced more casualties in the Bougainville campaign, the machinegun had the highest lethal effect.

TABLE 109.—*Percent distribution of 1,788 casualties (395 dead, 1,393 living wounded) by relative effectiveness of weapons* [1]

Weapon frequency	Percent of total	Weapon effectiveness	Relative lethal effect (percent)
Mortar	38. 8	Machinegun	57. 6
Rifle	24. 9	Rifle	32. 1
Grenade	12. 5	Artillery	22. 7
Artillery	10. 9	Mortar	11. 8
Machinegun	8. 4	Grenade	6. 2

[1] Mines and miscellaneous weapons are excluded (4.5 percent of total casualties).

A true measure of the effectiveness of a weapon cannot be obtained by a consideration of the total number of casualties and the relative lethal effect alone. A third factor must be considered; namely, the severity of the wound in the living. An estimate of the severity of the wound may be obtained by classifying the living casualties according to the ultimate disposition of the patient, whether he was returned to duty from the first or second echelon or evacuated to the United States. A still more important criterion of the effectiveness of a weapon from the standpoint of winning a battle is the ability of the wounded soldier to continue combat. This was determined by classifying the wounded according to arbitrary criteria based on whether the soldier could have continued combat for a few hours if his life were at stake (table 110). When measured by both of these standards, the relative effectiveness of the different weapons was found to be of the same order as follows: (1) machinegun, (2) rifle, (3) artillery, (4) mortar, (5) grenade.

Sufficient ballistics data were not available in this theater to determine the average velocity of shell fragments producing casualties. The exact size

of the shell causing these casualties was also unknown. Furthermore, there were insufficient clinical data to determine the size and mass of the fragments causing casualties. However, if one assumes that the average velocity of bullets is greater than that of shell fragments at the point of impact, these findings suggest that the effectiveness of a weapon is a function of the velocity of the missile.

TABLE 110.—*Percent distribution of casualties lost to battle and combat, by distribution and effectiveness of causative agent* [1]

[Values expressed as percentages according to type of weapon and effectiveness of weapon to total casualties]

Order of frequency	Lost to battle [2]		Lost to combat [3]	
	Weapon	Percent	Weapon	Percent
Distribution by weapon:				
1	Mortar	35. 7	Rifle	37. 7
2	Rifle	32. 3	Mortar	27. 6
3	Machinegun	12. 5	Machinegun	18. 4
4	Artillery	10. 6	Artillery	9. 5
5	Grenade	8. 9	Grenade	6. 8
Effectiveness of weapon:				
1	Machinegun	85. 4	Machinegun	75. 5
2	Rifle	74. 8	Rifle	52. 4
3	Artillery	56. 7	Artillery	30. 4
4	Mortar	53. 1	Mortar	24. 5
5	Grenade	40. 6	Grenade	18. 8

[1] Mines and miscellaneous weapons are excluded.
[2] Includes the dead and those casualties evacuated to the rear echelon or to the United States.
[3] Includes the dead or those casualties unable to continue to fight "if life were at stake."

Comparison of Japanese and U.S. Weapons.—A comparison of the effects of Japanese and U.S. weapons [20] showed a lower lethal effect for both the enemy artillery and the grenade. The fact that U.S. artillery was predominantly heavier than that of the Japanese may explain its greater relative effectiveness. The low lethal effect of the enemy grenade appeared to be characteristic of that weapon.

Circumstances.—On the basis of the study of a large group (79.9 percent) who had relatively little or no protection when wounded, it was found that the number of casualties depended upon random unaimed hits which were distributed roughly in proportion to the body area exposed. The remaining casualties which occurred under the circumstance of relatively good protection were equally distributed between the pillbox and the uncovered foxhole or trench. Aimed fire was responsible for 70.7 percent of the casualties in the uncovered trench or foxhole and for only 29.3 percent in the pillbox. On

[20] A comparison of weapons was possible in only a relatively small number of instances, since records were available for only 219 casualties produced by U.S. weapons.

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patrol and offensive action, the majority were wounded by the aimed fire, whereas, on defensive action, the reverse obtained. Eighty percent of the casualties in this study occurred during the Battle of the Perimeter.

A number of casualties resulted from careless exposure, failure to dig in, and failure to take advantage of natural cover. A large number of casualties (219) resulted from U.S. weapons. These findings indicate the need for even greater emphasis on the importance of cover. The training program should also stress the avoidable circumstances under which troops are killed or wounded by careless behavior.

Medical treatment.—Exceedingly advantageous circumstances surrounded the treatment of the wounded at Bougainville. In the treatment of 2,015 casualties, the low mortality of 3.7 percent was obtained. Experience in this campaign indicates a need for portable blood banks. Shock and hemorrhage were well treated by the liberal use of plasma. Whole blood transfusions were used more extensively than in any previous campaign in the South Pacific. Nevertheless, a wider utilization of blood transfusions would have been beneficial, because of the large blood volume replacement needed. Fractures were well treated by plaster immobilization. There were no deaths due to compound fractures of the extremities. First aid treatment was excellent and in only two instances did a death occur which might have been attributed to an aidman's error of judgment. Inadvisable evacuation of patients before recovering from shock possibly contributed to a fatal outcome in a few instances.

Post mortem examinations.—Hemorrhage was the most common cause of death in 104 autopsies. Frequently, 4 or more liters of blood were found in the pleural or peritonal cavities. Extensive brain damage ranked second in producing death. Accurate determination of the causative missile by the appearance of the wound was not possible in either the dead or the living. There was no constant relationship between the size of the wound of entrance and exit and the underlying structural damage. Temporary cavity effect of high-velocity missiles was frequently noted in the more solid organs as well as in the lung and brain.

CONCLUSIONS

The ultimate aim in the study of wound ballistics is to provide data which will permit the production of weapons which will produce more casualties among the enemy. These data may enable an army to devise more efficient weapons, develop better protective measures, and will eventually reflect in improving the care of the wounded.

Data Required

Field studies should yield information which permits the proper evaluation of weapons as casualty-producing agents. The effectiveness of a weapon may

be measured by the number of casualties it produces and by the severity of the wound. Wound severity in turn must be gaged not by local appearance but by the ultimate disposition or length of disability of the patient. The following factors, therefore, must be considered:

Weapons.—Type and proportion of weapons employed, the range or distance from the shellburst, and the mass or velocity of the missile should be determined.

Local circumstances.—The number and character of casualties reflect battle condition; hence, local conditions must be ascertained. It is desirable to know the position and occupation of the soldier when wounded, the available cover, terrain, and the tactical situation.

Medical care.—A detailed study of the patient's medical record is essential and should include a description of the wound, with the exact location of the point of entry, evaluation of the treatment, and post mortem findings in case of death. The degree of disability measured in time lost from combat must be ascertained and evaluated, together with the mortality rates for each weapon.

Methods and Results

Data in this chapter were obtained by personal interview and by questionnaire. Because the wounded man frequently knew less about the circumstances of wounding than his uninjured companion, witnesses were interviewed at the front as soon as possible after the action. Hospital staff officers were not trained in the study of wound ballistics, and when casualties were heavy they were fully occupied with the care of the wounded. For this reason, it was found desirable to have an officer of the ballistics team assemble clinical data at the various hospitals. Since the action was confined to a small geographic area and transportation facilities were excellent, the collection of essential information was relatively easy. Under these rather ideal circumstances, the report falls short of attaining the full advantage of the opportunity presented for the study of wound ballistics. Its merit, if such there be, lies in the fact that it presents data on all who were killed and wounded in one battle.

Lessons Learned

The personal interview is preferable to the questionnaire. The questionnaire may be utilized as an adjunct, if its use is supervised by a ballistics investigator and its accuracy repeatedly checked.

There is need for the definition and standardization of terms used in the study of wound ballistics. To obtain comparable reports, it is necessary to adhere to some uniform plan of collecting and recording data.

The number of the wound ballistics team personnel was inadequate. For a comparable volume of work, the number should be doubled.

A wound ballistics team[21] should be assigned to the combat unit a month before D-day. This will allow for indoctrination of medical officers, aidmen, and troops. In this interval, experienced team members can furnish valuable instruction by outlining the avoidable circumstances under which troops are killed or wounded.

Surgeons in hospitals along the line of evacuation should be instructed regarding the clinical data desired. They should understand the general objectives of the study in order to enable them subsequently to furnish the desired information.

The study of wound ballistics in the field requires special training and aptitude. It necessitates an attention to detail which an overloaded hospital staff does not have the time to devote during battle. Information collected in the routine manner without the aid of trained investigators lacks uniformity and accuracy. In order to collect adequate and accurate data, it is essential that a full-time wound ballistics team be assigned for that purpose.

[21] This could be identified as a battle casualty survey unit since it would be concerned with the identification of the types of battle casualties, the anatomic distribution of wounds, the causative agents, and the eventual disposition of the wounded. In addition, the ancillary factors contributing to the number of casualties should be investigated; for example, combat experience, type of action, and terrain. The survey team would also be in an advantageous position to collect information pertaining to other forms of trauma associated with modern day warfare. These could include vehicular accidents, bunker cave-ins, and airplane crashes. A casualty survey team should be an integral portion of the combat unit during peacetime maneuvers as well as in wartime. It is only in this way that a complete understanding of the purpose and scope of such a team could be adequately realized by the participating services. This unit should also investigate all accidents involving U.S. weapons during training procedures.—J. C. B.

CHAPTER VI

Examination of 1,000 American Casualties Killed in Italy

William W. Tribby, M.D. [1]

PURPOSE OF STUDY

The purpose of this study was to provide accurate source material on the distribution of wounds in the bodies of American soldiers killed in action. The project was conceived and initiated by Brig. Gen. (later Maj. Gen.) Joseph I. Martin, Surgeon, Fifth U.S. Army, who requested that it be done by personnel of the 2d Medical Laboratory. Fieldwork, restricted to the bodies of those who died before reaching field or evacuation hospitals, was begun on 29 April 1944 at the U.S. Military Cemetery, Carano, Italy, under the supervision of Col. Kenneth F. Ernest, MC, then commanding officer of the 2d Medical Laboratory. It was completed on 6 November 1944 at the U.S. Military Cemetery, Monte Beni, Italy, with the very helpful advice and direction of Lt. Col. (later Col.) Harold E. Shuey, MC, who became commanding officer of the laboratory in July 1944. Results of the study were presented in a six-volume report,[2] for which General Martin prepared the following foreword:

> It is quite apparent to anyone who has seen the human wastage in war that provisions for the best possible protection of the soldier from enemy fire on the battlefield have not been achieved, nor has the problem received the study it deserves. If the Medical Department is to carry out its mission fully, we should do our part in furthering improvement in this field. This study was conceived in that light and as a necessary step in the process of final solution of the problem.
>
> The extent of the effort required to complete this study should be apparent on the face of the data presented. It is only when it is known that this work was done as an additional

[1] The suggestions and assistance of Col. Charles G. Bruce, MC, Executive Officer, Office of the Surgeon, Headquarters, Fifth U.S. Army, facilitated the preparation of the original six-volume report. The author wishes to acknowledge his indebtedness to the following enlisted men of the 2d Medical Laboratory whose assistance made possible the work presented in the report: Sgt. Warren G. Dougherty, T4g. William E. McHale, T5g. Edward S. Werner, and Pfc. Ruben J. Anderson for their technical help in examining the bodies; and T4g. Arthur F. Labrado for the laborious task of typing the text, tables, and case descriptions. Special credit is due to Sergeant Dougherty for his invaluable assistance in assembling the data and for his faithful reproduction of the diagrams of the wounds. The well-executed outline form of the body, upon which the wounds were reproduced, was drawn by S. Sgt. John M. Watson, Office of the Surgeon, Headquarters, Fifth U.S. Army. The author wishes to thank the 47th Quartermaster Graves Registration Company for their willing and cheerful cooperation and the Fifth U.S. Army branch of the Army Pictorial Service for the use of one of their cameras and for their expert processing of the films and prints. The author is also indebted to Maj. Alfred G. Karlson for his suggestions and assistance in editing.

[2] This six-volume report, other than the part which serves as the basis for this chapter, consists of case reports on the 1,000 casualties examined. Since lack of space precludes inclusion of all 1,000 cases, representative case reports have been chosen for inclusion in this chapter (p. 454).

duty by hard pressed personnel of a very active field laboratory that the monumental scope of the undertaking is realized. The author has amply justified his right to ask that others, less actively engaged than he in the pursuit of the present conflict, develop the data presented here into terms of usefulness.

On several occasions it seemed that lack of time, obstinate weather of all kinds, the need for secrecy, the difficulty of working under battlefield conditions and the constantly changing military situation would contrive to halt this work. The reader is asked to consider these factors before becoming too critical. The completion of this unique project in its present form is a tribute to the indomitable desire for scientific investigation and [to the] * * * adherence to a high standard of scientific endeavor.

During the organization of the survey, it appeared that a study of this scope and character had not been done previously in the U.S. Army. Other casualty surveys were in progress (pp. 237–280 and pp. 281–436), but the details of the surveys were not available nor were either of them confined solely to the study of the killed in action. In the *Bulletin of the U.S. Army Medical Department*, No. 74, March 1944, a footnote to an article entitled "Need for Data on the Distribution of Missile Wounds" states: "The only data available in the Office of the Surgeon General are those from 1,175 Union soldiers who were killed in action during the Civil War. This footnote refers to the following statement:

> The records in this office [Surgeon General of the U.S. Army] show the seat of injury in only one thousand one hundred and seventy-three cases of soldiers killed on the battlefield. Of these, four hundred and eighty-seven (487) were of the head and neck, six hundred and three (603) of the trunk, thirty (30) of the upper extremities, and fifty-three (53) of the lower extremities.[3]

It is evident that a thorough study of these cases was not made.

It was believed that the contemplated survey would partially satisfy the need for data on the distribution of missile wounds. More specifically, it was hoped that the material would be useful in helping to devise one or more forms of body armor which could be used in some of the varying conditions encountered in battle. The data should also be useful to ballisticians although much of the material required by this group was unobtainable, as explained later.

METHODS OF STUDY

It was decided that this work should be done in the U.S. military cemeteries because it is here that bodies become available in groups large enough to make possible the study of a thousand cases within a reasonable period of time. Information regarding the circumstances attending death could not be augmented by working farther forward. Furthermore, the removal of clothing from bodies cannot be permitted before they have been searched for identification tags and personal effects by personnel of the Graves Registration Service in preparation for burial. This latter function was performed in the ceme-

[3] Medical and Surgical History of the War of the Rebellion. Surgical History. Washington: Government Printing Office, 1883, pt. III, vol. II, pp. 691–692.

teries. The data for this study, therefore, were collected in the U.S. military cemeteries at Carano, Follonica, Castelfiorentino, and Monte Beni, Italy. The periods of time and numbers of cases studied in each location are shown in table 111.

TABLE 111.—*Period of time, location of cemetery, and number of cases studied at each cemetery*

Date	Location	Cases studied
1944		*Number*
29 April–27 May	Carano	250
4–20 July	Follonica	240
6–21 October	Castelfiorentino	328
27 October–6 November	Monte Beni	182

Quartermaster Graves Registration Service

The methods employed by the Quartermaster Graves Registration Service for collection and delivery of bodies to the cemeteries are related to certain aspects of this study, and they merit brief description. The division quartermaster is responsible for evacuation of bodies to the Graves Registration Service. He, or his appointed representative, may act as the divisional graves registration officer. Each regiment has a graves registration officer who organizes collecting teams. These teams are composed of enlisted men who collect the dead and write the EMT's (emergency medical tags). One platoon of a graves registration company is capable of operating a cemetery provided the number of burials is not too great. In Italy, it was usually possible for the 47th Quartermaster Graves Registration Company to have one of its platoons operate four collecting points so spread out behind the front as to cooperate with the divisional collecting teams. It was intended that regimental collecting teams would evacuate their dead to Graves Registration Service collecting points whence they were evacuated to the cemetery. This plan was not always followed because at times the regimental collection point was closer to the cemetery than it was to a Graves Registration Service collecting point. In static situations, the divisional collecting and evacuation system usually functioned without delay in cooperation with the Graves Registration Service. Most bodies were recovered promptly. However, when the army was advancing rapidly and actions occurred in widespread areas, it was more difficult to find bodies, and frequently they did not reach the cemetery for many days after death. When the divisional collecting system was forced to leave bodies behind, the task of finding and collecting them fell to the Graves Registration Service.

Examinations

Bodies were examined as received in the cemeteries, without selection but with the requirement that they be in a condition fit for examination; that is,

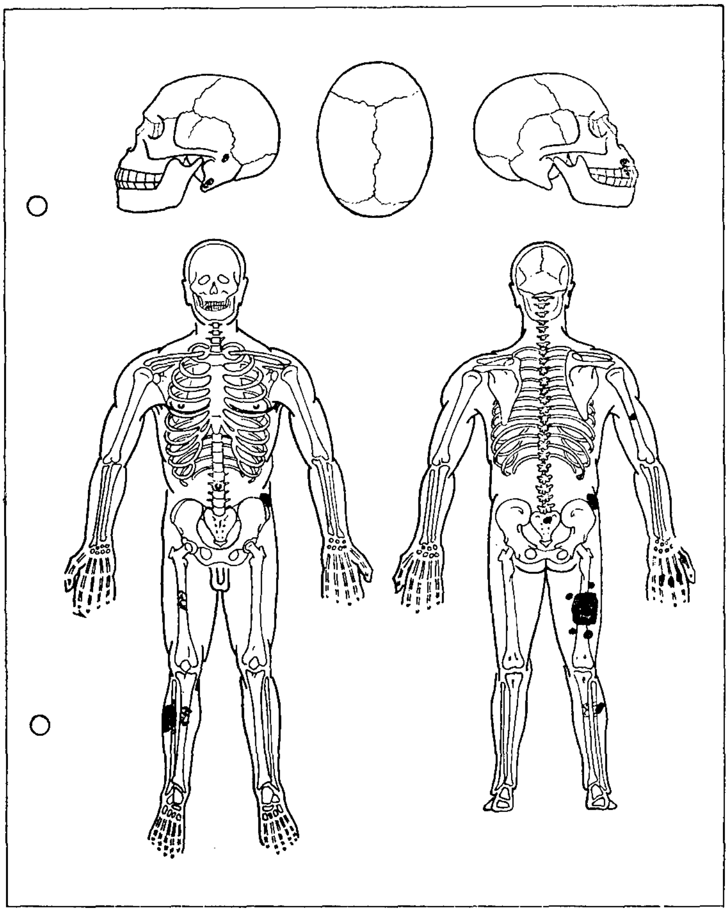

FIGURE 229.—Worksheet with anatomic views of body and location of wounds.

not so decomposed nor so heavily infested with fly larvae as to make the location or extent of the wounds uncertain. In practice, the bodies were stripped of all clothing after having first been searched by graves registration personnel. The wounds were then described and recorded promptly so as not to delay interment. Every wound was probed and its extent determined as exactly as possible from external examination.

All data were recorded on mimeographed sheets on one side of which were outline forms of front and rear views of the body with three views of the head. Rough sketches of the wounds were made (fig. 229). On the reverse of the sheet was entered identifying information to include, when available, name, rank, Army serial number, organization, army branch of service, type of missile, type of action, position at time of injury, treatment, and description of wound and wound track. This information is essentially the same as that suggested

in the article in the March 1944 Medical Department bulletin. The worksheets were saved as a permanent record.

Certain difficulties were encountered in attempting to obtain the items of information just cited. All of these items, except descriptions of wounds and names and serial numbers, had to be obtained from EMT's or from Graves Registration forms. Names and serial numbers were usually copied from identification tags. When the latter were missing, other means of identification were sought, such as AGO cards, letters, and membership cards. Ranks, organizations, and serial numbers could not always be recorded at the time when the bodies were examined. After 1,000 cases had finally been studied, it was found that information on approximately one-third was incomplete. The missing data were obtained from the office of the Fifth U.S. Army Graves Registration Officer and the Adjutant General Casualty Section.

Causative Agents

Efforts to ascertain and tabulate the missiles in this series met with almost insurmountable difficulties. A man killed in battle will be seen to fall only by his comrades who cannot know with certainty what type of missile caused a man's death. They may know that a man was hit by machinegun or rifle fire or that he encountered a mine, but they cannot state with accuracy the caliber of a high explosive shell which has been fired at them. In any event, even if accurate information regarding missiles is known to a man's comrades, it does not often find its way to the EMT's which are filled in by company aidmen or other medical personnel who arrive on the scene after the action has occurred. Those who actually see the death occur are seldom present when the body is tagged. Ballistic data on EMT's cannot therefore be depended upon since it is not known which ones are accurate. The best method of obtaining accurate information of this type is to perform an autopsy to locate and identify missiles [4] (fig. 230) and to determine the extent of tissue damage. Early in this study, it became evident that the performance of an autopsy in every case was impracticable because of the time required for such a procedure. The first body autopsied in this project was thoroughly dissected in search of the missile. After a period of 3 hours, the missile had still not been found, and the search for it was abandoned. Even when fragments of metals are found, their small size usually precludes determination of their origin. Frequently, missiles were discovered near the surface of the body, in wounds, or in the clothing adjacent to wounds. The size and shape of all such pieces of metal were incorporated in

[4] This information should be supplemented by interviews with soldiers present at the time the man was wounded. They can identify the causative agent with a surprising degree of accuracy and can also furnish invaluable data pertaining to type of activity, position of soldier, terrain and protective cover, and approximate range. Therefore, surveys on killed-in-action casualties should be conducted by two teams working simultaneously but in widely separated locations. One team should be available for interrogation of eyewitnesses in the forward area where the body is recovered. This team can be composed of nonmedical personnel. The second team, composed of medical and certain essential nonmedical personnel. should be located at the main collecting point for the bodies (interment site or current death embalming area) where a complete wound ballistics examination can be conducted. Ideally, the latter should entail a complete external examination of the wounds with their location and description, adequate color photographs of the wounds, X-ray examination, autopsy examination of the major wounds, recovery of missiles, photographs and preservation of gross organs, preparation of tissue blocks, and determination of cause of death.—J. C. B.

FIGURE 230.—High explosive steel fragments (primary missiles). All of these fragments were retained in and removed from the fatal wounds of infantrymen killed in action with the Fifth U.S. Army in Italy. The fragments range from 1 to 120 grams in weight.

the descriptions of each case. The data concerning missiles were copied from the EMT's with the important exception that the term "high explosive" did not occur on the tags. Under this heading were placed all casualties who obviously died as the result of having been hit by high explosive missiles but whose EMT's did not indicate a missile. Also included in this category were all cases for which there was definite evidence that the missile was erroneously stated on the EMT but which were manifestly hit by high explosive missiles. It was believed that the data as finally recorded on the case report were in general accurate with regard to gross categories of causative agents.

Problems Encountered

In warm weather, the condition of most of the bodies received in the cemeteries was so unsatisfactory that even external examinations were not done. During the months of August and September, the work was discontinued because too few bodies in fresh condition were received at the cemeteries to make an effort worth while. For this reason, the proportion between the number of cases included in this series and the number of interments varied considerably from one cemetery to another. For example, the sample of battle deaths included in this study was larger at Castelfiorentino in October than it was at Follonica in July.

The 1,000 casualties of the survey though not representative of casualties from all types of action during different seasons were not significantly different from those observed in areas other than where the survey was conducted. There was also no apparent difference in the types of cases received when the front was static as compared with those received during an offensive.

The exact type of action in which these battle casualties occurred could not be determined at the cemeteries. The available information consisted of the location where bodies were recovered, which was indicated on a majority of the emergency medical tags. The usual statement consisted of "Vic [victim] of," followed by the name of the nearest landmark or inhabited locality, often misspelled. Coordinates were usually not given. To obtain accurate type-of-action data, it would be necessary to study the history of each organization.

The position of the body at the time of injury could not be determined because it was impossible to make contact with anyone able to give this information.

As it was impossible to obtain the services of a photographer for an extended period of time, a camera was borrowed from the Army Pictorial Service. Photographs of 82 representative cases were made by the author and processed by the Army Pictorial Service (fig. 231). The photographs were made under an agreement with the Fifth U.S. Army Graves Registration Officer that no names would be associated with them.

STATISTICAL STUDIES

At the beginning of the description of each case in the complete report is a statement which classifies the wounds as single or multiple and lists the various parts of the body which are involved. Tables 112, 113, 114, 115, and 116 are presentations of these data in tabular form. Each wound is mentioned separately in most of the cases except in instances where multiple wounds were present. In the latter cases, each wound is not described separately.

FIGURE 231.—Typical photograph of a casualty (Case No. 635) with multiple fatal and nonfatal wounds due to high explosive shell fragments. There are many penetrating wounds in the posterior surface of the torso and left arm varying from a few millimeters to 11 x 12 centimeters. This largest wound is a penetrating laceration in the left buttock and sacral area.

Classification

A compilation of the cases, arranged according to parts of the body which were affected and according to probable missiles, is presented in table 112. Emphasis must be placed upon the word "probable" when reference is made to missiles. It must not be forgotten that the placing of the majority of the cases in any particular group, with respect to missiles, is based upon the appearance of wounds and EMT data rather than upon actual finding of missiles. The columns labeled "Upper half of the body" and "Lower half of the body" list the cases which had wounds confined to the areas above and below the diaphragm, respectively, but with more than one region involved. The column labeled "Upper and lower halves of the body" lists the cases in which the wounds were distributed above and below the diaphragm. It will be seen that some of the cases in these three columns have single wounds. This means that from external examination it was determined that more than one region was affected. For example, a single wound in the chest, with intestine herniated through it, is of the thoracoabdominal type, and the case belongs in the group of cases with wounds both above and below the diaphragm. Undoubtedly, many of the cases with wounds which were too small to be probed would have been

found to have parts affected other than those listed had it been possible to perform autopsies in all such instances. The data, however, were uniformly recorded from the standpoint of external examination.

TABLE 112.—*Distribution of 983 KIA casualties,[1] according to body areas and probable causative agents*

Probable causative agent [2]	Head	Neck	Thorax	Abdomen	Upper extremity	Lower extremity	Upper half of body	Lower half of body	Upper and lower halves of body	Pelvis	Total
	Casualties with single wounds										
High explosive	61	1	31	6	3	7	4	5	9	2	129
Shell fragments	39	5	26	7	4	8	6	------	4	----	99
Small arms	24	7	27	3	3	2	7	3	2	3	81
Total	124	13	84	16	[3] 11	17	17	8	15	5	[3] 310
	Casualties with multiple wounds										
High explosive	7	1	16	1	------	14	87	14	202	----	342
Shell fragments	1	----	9	----	1	8	55	8	201	----	283
Small arms	1	----	4	----	------	1	9	------	11	----	26
Total	9	1	29	1	1	23	[4] 154	22	[5] 433	----	[4,5] 673
Grand total	133	14	113	17	12	40	171	30	448	5	983

[1] Does not include 4 casualties cremated in a tank and 13 casualties due to blast injury. See text, p. 446.

[2] Identified from appearance of the wound and from information on EMT's rather than by recovery of the actual missile.

[3] Includes a wound caused by a landmine.

[4] Includes 3 wounds caused by landmines.

[5] Includes 19 additional wounds—3 caused by hand grenades, 15 by landmines, and 1 by aerial bombs.

Some difficulty was encountered in attempting to classify wounds located in marginal areas; for instance, deciding whether axillary wounds should be listed as upper extremity wounds or as chest wounds. Axillary and shoulder girdle wounds were classified as chest wounds except in cases where they extended into or were distal to the head of the humerus. The same criteria were applied to wounds in the inguinal and buttock areas where they were classified as pelvic unless they extended into or were distal to the head of the femur. The terms "back" and "lumbar area" were not included in the classifications. Wounds located in the back above the level of the first lumbar vertebra were listed as "chest." Similarly, posterior wounds in the lumbar region above the iliac crests were classified as abdominal.

Four cases [5] were classified as cremation in a tank, and thirteen cases were designated as blast injury. (These 17 cases are not included in table 112.) The latter cases were those with nonpenetrating wounds with blast injury the probable cause of death. Autopsies were performed upon four of these bodies and diffuse pulmonary hemorrhage was found in all four cases and pulmonary edema in three of them. Microscopic tissue studies were done in only one of the cases, the others having been decomposed to such an extent that tissues were not saved for this purpose. All cases in this group, except one, showed the presence of blood either in the nose or mouth or in body places. This finding, in the absence of penetrating wounds, was presumed to indicate pulmonary hemorrhage probably due to blast. Several other cases, without penetrating wounds sufficient to explain death, may have died of blast injury.

Even though the actual missiles were not recovered, the general breakdown of the causative agents was comparable to that determined in other ground force casualty surveys where witnesses were interrogated and autopsies were performed. Small arms accounted for 107 (10.9 percent) of the 983 missile-wounded casualties. Fragment-producing weapons were tentatively identified in the remaining 876 (89.1 percent) of these casualties. Shell fragments were identified with certainty in 382 (38.9 percent) of the casualties. However, the noncommittal term "high explosive" was used for 471 (47.9 percent) of the cases, and it was presumed that most of the missiles were derived from mortar and artillery shells. Hand grenades were positively identified in 3 (0.1 percent) of the casualties, landmines in 19 (1.9 percent), and aerial bombs in 1 (0.1 percent). If the exact identification of the missiles could have been made, the proportion of hand grenade and landmine casualties might have increased.

Multiple Wounds

From the group of cases with wounds involving the upper half of the body, the lower half of the body, and the combined upper and lower halves of the body, data were compiled on regional incidence (number of times an anatomic region was involved). These data are presented in tables 113, 114, and 115. Table 116 is a compilation of all the data on actual distribution of wounds in the whole series and also lists the regional frequency of the probable lethal wounds. The thorax was most frequently involved, followed, in order, by the head, the upper and lower extremities, and the abdomen.

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[5] The author had originally included these cases with the casualties receiving missile-inflicted injuries (upper and lower halves of the body). Since only a few pounds of charred body remains were recovered, it is felt that they should be considered in a separate category.—J. C. B.

TABLE 113.—*Distribution of 396 injuries in 171 cases with wounds confined to the upper half of the body but with more than one region involved, by anatomic location*

Anatomic location	Number of wounds	Percent of cases
Head	88	51. 5
Neck	67	39. 2
Thorax	120	70. 2
Upper extremity	121	70. 8

TABLE 114.—*Distribution of 67 injuries in 30 cases with wounds confined to lower half of the body but with more than one region involved, by anatomic location*

Anatomic location	Number of wounds	Percent of cases
Abdomen	20	66. 6
Pelvis	24	80. 0
Genitalia	2	6. 6
Lower extremity	21	70. 0

TABLE 115.—*Distribution of 1,648 injuries in 452 cases*[1] *with wounds involving regions both above and below the diaphragm, by anatomic location*

Anatomic location	Number of wounds	Percent of cases
Head	210	46. 5
Neck	97	21. 5
Thorax	339	75. 0
Abdomen	232	51. 3
Pelvis	146	32. 3
Extremities:		
Upper	276	61. 1
Lower	327	72. 3
Genitalia	21	4. 6

[1] Includes 4 cases cremated in a tank not included in table 112.

With a view to determining the approximate total number of wounds and their regional distribution, the author's original case reports were reexamined.[6] The total number of cases (983, table 112) remained the same, but a slight change was made in the distribution of the single and multiple regional involvements (missile wounds), as follows:

		Number of cases
Single region involved:		
Head		138
Neck		21
Thorax		126
Abdomen		25
Extremities:		
Upper	18	
Lower	72	
		90
Total		400
Multiple regions involved		583
Grand total		983

No change in classification was made for the 4 cases cremated in a tank and the 13 casualties which were due to blast injury, and they were not included in any of the tabulations.

Reevaluation

In the original tabulation, a number of cases with perforating wounds had a missile track involving several body regions and were classified as multiple-region-type cases. It was decided that these should be considered as a single-region involvement of the entrance site regardless of the location of the exit wound. The demarcation of the anatomic regions was also based upon slightly different criteria [7] and accounts for some of the changes in the regional frequency of wounds (table 117, compare with table 116). The buttocks, though considered as a portion of the lower extremity, were listed separately because of interest in this region in the development of lower torso body armor. Table 118 lists the regional distribution of the estimated 7,006 wounds in the 983 casualties. Of the total wounds, 55.4 percent (more than a half) occurred in the extremities and 25.7 percent were located in the thorax. Approximately 6,130 (87.5 percent) were penetrating [8] type of wounds and 876 (12.5 percent) were perforating [9] type of wounds. The wound incidence per casualty was approximately 7.1 percent, and this is very similar to that found in the study of KIA in the Korean War.

[6] By the editor (J. C. B.).

[7] Holmes, R. H., Enos, W. F., and Beyer, J. C.: Demarcation of Body Regions and Battle Casualty Analysis. U.S. Armed Forces M. J. 5: 1610-1618, November 1954.

[8] Wound of entrance only and major portion of missile retained within the body.—J. C. B.

[9] Wounds of entrance and exit and major portion of missile not retained within the body.—J. C. B.

TABLE 116.—*Distribution of 2,445 injuries in the various groups of the 987 KIA casualties,*[1] *by anatomic location and probable fatal wounds*

Anatomic location	Regional involvement in groups with wounds of—				Total wounds		Probable fatal wounds [2]	
	Upper half of body (171 cases)	Lower half of body (30 cases)	Upper and lower halves of body (452 cases)	Single region (334 cases)	Number	Percent	Number	Percent
Head	88		210	133	431	17. 6	401	28. 1
Neck	67		97	14	178	7. 3	121	8. 5
Thorax	120		339	113	572	23. 4	422	29. 6
Abdomen		20	232	17	269	11. 0	167	11. 7
Pelvis		24	146	5	175	7. 2	79	5. 5
Extremities:								
Upper	121		276	12	409	16. 7	98	6. 9
Lower		21	327	40	388	15. 9	138	9. 7
Genitalia		2	21		23	. 9		
Total	396	67	1, 648	334	2, 445	100. 0	1, 426	100. 0

[1] Includes 4 casualties cremated in a tank and not included in table 112.
[2] Included in total wounds but probably responsible for mortality.

TABLE 117.—*Distribution of 2,183 regional involvements*[1] *in 983 KIA casualties, by anatomic location (regional frequency)*

Anatomic location	Regional involvement		Total regional involvement		Regional frequency in 983 cases
	Single wound (400 cases)	Multiple wounds (583 cases)	Number	Percent	
					Percent
Head	138	258	396	18. 1	40. 3
Neck	21	128	149	6. 8	15. 1
Thorax	126	390	516	23. 6	52. 5
Abdomen	25	192	217	10. 0	22. 1
Extremities:					
Upper	18	358	376	17. 2	38. 2
Lower	68	342	410	18. 8	41. 7
Buttocks	4	115	119	5. 5	12. 1
Total	400	1, 783	2, 183	100. 0	

[1] Indicates frequency of anatomic regional incidence of wounds per casualty but not total number of wounds.

TABLE 118.—*Distribution of 7,006 wounds in 983 KIA casualties, by anatomic location (regional distribution)*

Anatomic location	Regional distribution of wounds		Total wounds	
	Single wound (400 cases)	Multiple wounds (583 cases)	Number	Percent
Head	156	458	614	8. 8
Neck	21	238	259	3. 7
Thorax	186	1, 616	1, 802	25. 7
Abdomen	26	420	446	6. 4
Extremities:				
Upper	21	1, 439	1, 460	20. 8
Lower	275	1, 806	2, 081	29. 7
Buttocks	10	334	344	4. 9
Total	695	6, 311	7, 006	100. 0

Rank and Type of Duty

The rank and type of duty of the 1,000 killed in action examined are listed in the following tabulations:

Rank:	*Number*
Private	454
Private, first class	277
Technician, fifth grade	33
Corporal	34
Technician, fourth grade	12
Sergeant	67
Staff sergeant	42
Technical sergeant	18
Sergeant, first class	4
2d lieutenant	31
1st lieutenant	15
Captain	10
Major	2
Lieutenant colonel	1

Type of duty:	*Number*
Infantry and armored infantry	875
Field artillery	27
Tank	27
Engineer	21
Infantry medical detachment	13
Tank destroyer	9
Chemical	8
Reconnaissance	7
Antiaircraft artillery	5
Signal	4
Division headquarters	1
Division headquarters, Military police	1
Division band	1
Medical battalion	1

Emergency Medical Tag

Of the EMT's attached to the bodies examined, 119 gave indication that the casualties had been seen alive after having been hit. Data collected partly by examination of the bodies and partly from EMT's showed that 109 of the cases had received the following types of treatment:

	Number treated		*Number treated*
Sulfonamide, local	80	Tourniquets	9
Dressings	89	Sulfonamide, tablets	2
Plasma	27	Oxygen	1
Splints	16	Shock therapy	2
Medicine (for example, morphine)	9		

For the remaining 10 cases listed as "WIA" on Graves Registration Burial Forms (GRS No. 1), no treatment was noted.

At the time this study was being done, diagnoses from the EMT's were not copied on the worksheets. The diagnoses on the tags were not changed or influenced by this study except in six cases which were autopsied. It became evident as the study progressed that diagnoses on EMT's were often erroneous. Since EMT's were frequently the only source of information on battlefield deaths available to the Medical Department, an effort was made to determine the accuracy of the diagnoses contained thereon. The EMT diagnosis was obtained for each case in this study from the Graves Registration Burial Form No. 1. A comparison of the diagnoses is presented in table 119. It is seen, for example, that 15.3 percent of the EMT's for these 1,000 cases had erroneous diagnoses for wounds of the head and 13.9 percent were in error for wounds of the neck. For the abdomen and pelvis, the errors were 20.2 percent and 16.3 percent, respectively. This deficiency was only partially the fault of those who wrote the EMT's for battlefield deaths. Accurate diagnoses are not to be expected unless the body is stripped of all clothing and examined by a medical officer.[10]

TABLE 119.—*Comparison of regions actually involved and regions recorded on EMT's*

Body region	(1) Region actually involved	(2) Regional involvement present and noted on EMT	(3) Noted on EMT and not actually present	(4) Number of EMT's with errors [1]	(5) Percentage o errors in EMT's in 1,000 cases
Head	431	327	49	153	15. 3
Neck	178	58	19	139	13. 9
Thorax	572	338	42	276	27. 6
Abdomen	269	114	47	202	20. 2
Pelvis	175	26	14	163	16. 3
Extremities:					
Upper	409	113	42	338	33. 8
Lower	88	190	34	232	23. 2
Genitalia	23	3	3	23	2. 3
Total	2, 445	1, 169	250	1, 526	100. 0

[1] Figures in column 1 minus figures in column 2 plus figures in column 3.

[10] In addition, the EMT could be designed to contain several small anatomic outlines so that the exact location of all wounds could be quickly but accurately located.—J. C. B.

Indication for Body Armor

The following 198 cases with severe multiple mutilating wounds (figs. 232 and 233) are grouped according to the regions affected:

Group with—	*Number of cases*
Severe wounds involving the head, including decapitations and crushing and mutilating wounds (20 of this group are included in one or more of the other groups listed)	103
Traumatic amputation of all or part of one lower extremity (10 of this group are included in one or more of the other groups listed)	33
Traumatic amputation of all or part of both lower extremities (12 of this group are included in one or more of the other groups listed)	23
Traumatic amputation of all or part of one upper extremity (18 of this group are included in one or more of the other groups listed)	33
Traumatic amputation of all or part of both upper extremities (10 of this group are included in one or more of the other groups listed)	12
Other mutilating or dismembering wounds (29 of this group are included in one or more of the other groups listed)	54

FIGURE 232.—Traumatic (partial) decapitation due to high explosive shell. Vault of skull laid open and brain completely eviscerated. Severe fragmentation of the bones of the vault and of bones of base of skull on left side.

FIGURE 233.—Extensive multiple and mutilating wounds of all regions of the body due to high explosive shell. A. Front of body. B. Back of body. C. Multiple wounds of lower extremities. There is almost complete dismemberment of the upper half of the body from the iliac crests upward. The head is missing. The chest and abdomen are completely mutilated and laid open from a posterior direction. Both arms are attached to the remainder of the body by segments of skin. Numerous lacerated penetrating wounds are found in both legs.

These 198 cases plus 4 which were cremated represent 20 percent of the total number examined which could not have been saved from death by any type of body armor.

In many cases with multiple wounds, it is difficult to determine which wound is the immediate cause of death. Undoubtedly, some of the traumatic amputations of extremities would not have resulted in death had they been the only wounds. Wounds of the head were considered as more likely to have been fatal than wounds of other regions. Of 432 head wounds, only 31 were either nonpenetrating or not serious enough to have been fatal. Although no study has been made to determine the percentage of head wounds involving the areas not protected by the helmet, the impression was obtained that a helmet could be designed to cover more of the head and neck and reduce the number of serious wounds of these regions. Other sites which would be difficult to protect by armor are the attachments of the extremities to the trunk, of which no studies were made in this report. About 20 percent of the cases could not have been protected by any type of body armor. Possibly some type of body armor could be designed to protect vital areas most often involved, such as the head and trunk. The data in the original report are source materials which can be studied further in an attempt to clarify this problem.

CASE REPORTS

The case reports which are included in this section were selected from the original report as illustrative of the types of wounds inflicted on the various anatomic regions of the casualties studied in this survey. In all instances, the case numbers assigned in the original report have been used.

HEAD

Case No. 633.—Pfc., 168th Infantry, 14 Oct. 1944; missile: high explosive; single wound in the head (fig. 234). There was a through-and-through wound in the head with the wound of entrance, 2 x 4 cm., in the left cheek area and the wound of exit, 3.5 x 5 cm., in the right temporal and zygomatic area, passing through the external ear. The right temporal bone and bones of the face were severely crushed.

Case No. 641.—Pvt., 338th Infantry, 15 Oct. 1944; missile: shell fragments; multiple wounds in the head (fig. 235); treatment: plasma, 2 units local sulfonamide and dressing. Three deep lacerations were present in the right posterior half of the head. The right temporal bone was penetrated immediately behind the external ear in an area which measures 3 cm. in diameter.

FIGURE 234.—Single head wound. A. Wound of entrance. B. Wound of exit.

FIGURE 235.—Multiple wounds of the head.

NECK

Case No. 501.—Pfc., 362d Infantry, 7 Oct. 1944; missile: shell fragment; single wound in the neck (fig. 236). A large mutilating wound was present in the left anterior and lateral sides of the neck. There was exposure and fragmentation of several cervical vertebras.

FIGURE 236.—Single neck wound.

Case No. 970.—Pfc., 362d Infantry, 5 Nov. 1944; missile: shell fragment; single wound in the neck (fig. 237). A wound, 1.3 x 2.5 cm., penetrated the anterior side of the neck immediately to the right of the midline and immediately inferior to the larynx. The trachea was perforated and the body of the C7 vertebra was crushed. The wound bled profusely.

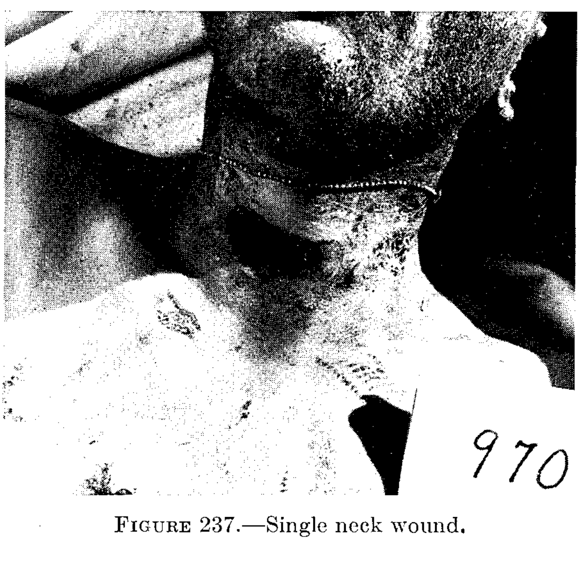

FIGURE 237.—Single neck wound.

CHEST

Case No. 760.—Pvt., 338th Infantry, 19 Oct. 1944; missile: high explosive; single wound track in the chest (fig. 238). This through-and-through wound had its entrance, 1 x 2.5 cm., in the posterior left side of the chest at the level of the T5 vertebra, 10 cm. from the midline. The wound of exit, 4 x 6 cm., was located in the anterior left side of the chest at the level of the second and third ribs. There was a large opening into the thoracic cavity through the second, third, and fourth ribs.

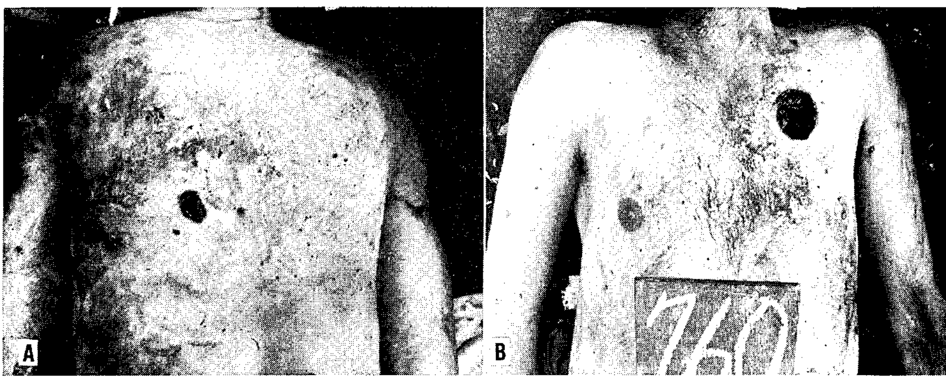

FIGURE 238.—Single chest wound. A. Wound of entrance. B. Wound of exit.

Case No. 824.—Pfc., 936th Field Artillery, 27 Oct. 1944; missile: shell fragments; multiple wounds in the chest (fig. 239). There was a through-and-through wound in the chest with the entrance, 2 x 2.5 cm., in the left anterior axillary line. The wound track traversed the thoracic cavity in a slightly posterior and medial direction through compound comminuted fractures in the fourth and fifth ribs. The wound of exit, 3.5 x 4 cm., was located in the anterior lateral right side of the chest, where it passed through a compound comminuted fracture in the fifth rib. A superficial through-and-through lacerated wound was present in the posterior left side of the chest in the midscapular area. Another laceration was found near the medial angle of the right scapula.

FIGURE 239.—Multiple wounds of the chest.

603225°—62——31

Case No. 908.—Sgt., 755th Tank Battalion, 1 Nov. 1944; missile: high explosive; single wound track in the chest (fig. 240). This through-and-through wound in the chest had its entrance, 2 x 2.5 cm., through the body of the left pectoralis muscle group, near the axilla. The track proceeded downward and posteriorly through the fractured third rib. The wound of exit, 2.5 cm. in diameter, was found in the posterior side of the chest, immediately to the left of the midline at the level of the T4 vertebra. The wound opened into the spinal canal through the T4 and T5 vertebras and extended to the left of the spinal column into the thorax. The left fourth rib was fractured transversely at the site of exit.

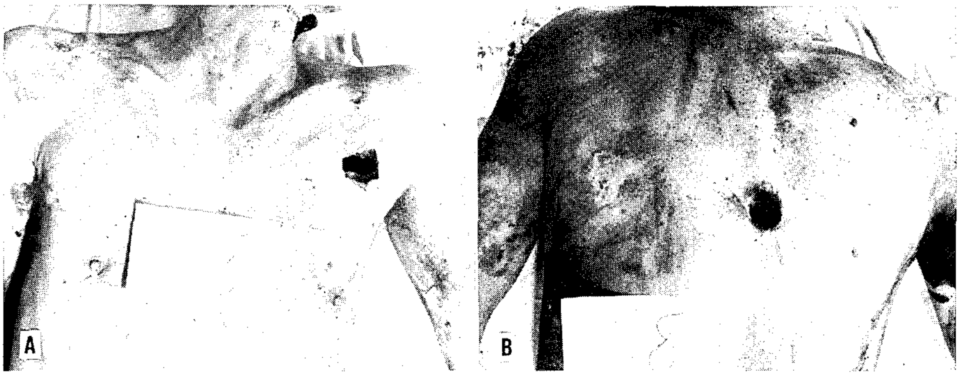

FIGURE 240.—Single thoracic wound. A. Wound of entrance. B. Wound of exit.

ABDOMEN

Case No. 986.—Pvt., 363d Infantry, 5 Nov. 1944; missile: high explosive; single wound in the abdomen (fig. 241); treatment: local sulfonamide and dressings. A penetrating wound, 6.5 cm. in diameter, was located in the midline of the abdomen in the epigastrium. There was evisceration of numerous loops of small intestine through the wound.

FIGURE 241.—Single abdominal wound.

LOWER EXTREMITY

Case No. 644.—Pfc., 338th Infantry, 14 Oct. 1944; missile: high explosive; multiple wounds in both lower extremities (fig. 242). There was traumatic amputation of both legs immediately distal to the knee joints. Lacerations extended into the distal medial third of the left thigh.

FIGURE 242.—Multiple wounds of lower extremities.

Case No. 759.—Cpl., 337th Infantry, 19 Oct. 1944; missile: high explosive; multiple wounds in both lower extremities (fig. 243). Numerous penetrating wounds were found in the left leg between the knee and the ankle. They varied in diameter from 1 cm. to 2.5 cm. There was traumatic amputation of the right leg through the middle third. The distal portion was attached by muscle and was completely mutilated. Two lacerated penetrating wounds were present in the lateral and anterior sides of the right knee. There was a compound comminuted fracture in the right patella. A laceration, 3 x 5 cm., was located in the anterior side of the right knee and leg. Maggots, visible in figure 243, were contaminants from another body.

Case No. 966.—Pfc., 339th Infantry, 4 Nov. 1944, missile: high explosive; multiple wounds in both lower extremities (fig. 244); treatment: local sulfonamide and dressings. There was traumatic amputation of the left leg through the proximal third of the tibia and fibula, with lacerations extending into and above the knee joint for a distance of 10 cm. There was essential traumatic amputation of the right foot through the ankle joint with severe mutilation of the entire foot; lacerations extended 12 cm. above the distal end of the tibia and fibula. Two intercommunicating lacerations in the right medial thigh were 6 cm. apart; the lower opening measured 1.5 x 2.5 cm. and the upper opening, 4 x 5 cm. A superficial laceration, 3.5 cm. in diameter, was found in the anterior proximal aspect of

the right thigh. There was a comminuted fracture in the middle third of the right femur, with a penetrating wound over the fractured area in the middle of the thigh, anteriorly. A laceration, 2 x 4 cm., in the medial side of the right leg exposed the periosteum of the tibia.

FIGURE 243.—Multiple wounds of the lower extremities.

FIGURE 244.—Multiple wounds of the lower extremities.

MULTIPLE WOUNDS

Case No. 80.—T5g., 338th Infantry, 15 May 1944; missile: shell fragments; multiple wounds in the head, neck, chest, and both upper extremities (fig. 245). A penetrating wound, 1 x 2 cm., was present in the vertex of the skull in the midline; the point of exit, 4 cm. in diameter, was located in the right parietal region; there was avulsion of brain tissue and extensive lacerations of the scalp. A through-and-through wound was noted in the right side of the neck: The point of entry, to right of the larynx anteriorly, was 1 cm. in diameter; the point of exit, 4 cm. in diameter, was at the anterior border of the trapezius muscle; two other small penetrating wounds were seen in the right side of the neck posteriorly. A penetrating wound, 3.5 cm. in diameter, was found in the left shoulder over the upper portion of the scapula; there were many other small penetrating wounds of both shoulders, posteriorly, and of the right arm and shoulder, anteriorly. A penetrating wound was present in the base of the left thumb. There was traumatic amputation of the right hand immediately distal to the wrist joint.

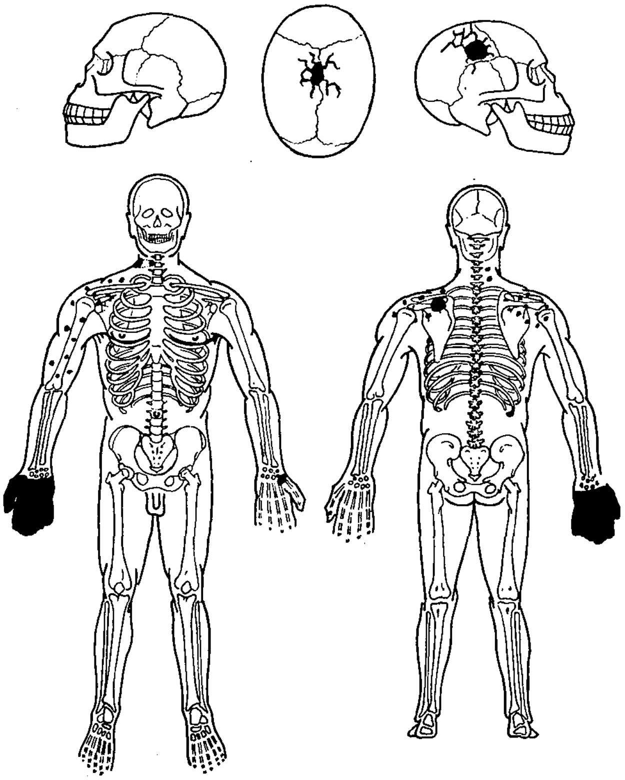

Figure 245.—Multiple wounds.

Case No. 631.—Pvt., 133d Infantry, 14 Oct. 1944; missile: high explosive; multiple wounds (two) in the chest and left upper extremity (fig. 246). There was traumatic amputation of the left arm through the proximal end of the humerus. The joint cavity was not involved. The arm remained attached by a small segment of skin. The wound extended into the left upper anterior side of the chest where the skin and muscles were extensively mutilated. A laceration, 4 x 6 cm., was located in the left lateral aspect of the thorax.

FIGURE 246.—Multiple wounds of the chest and the left upper extremity.

Case No. 678.—T. Sgt., 361st Infantry, 15 Oct. 1944; missile: shell fragments; multiple wounds in the head, neck, chest, and both upper extremities (fig. 247). Many penetrating wounds were found in the face, anterior neck, chest, left arm and shoulder. They varied in diameter from a few millimeters to 1.5 centimeters. The largest wound entered the chest anteriorly, at the level of the sixth intercostal space 6 cm. from the midline through

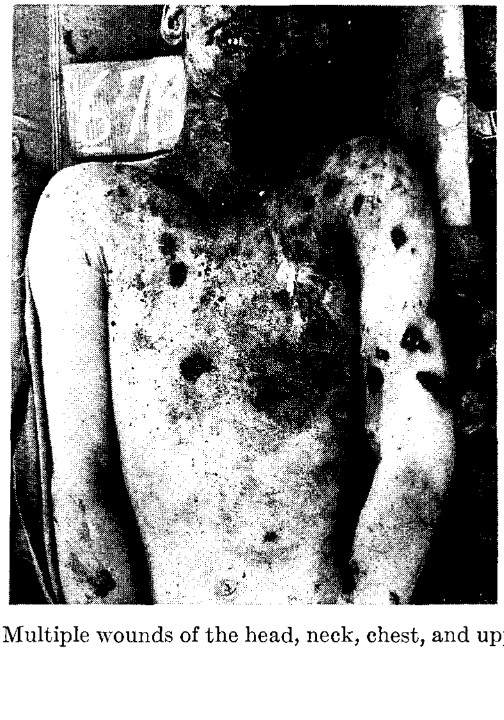

FIGURE 247.—Multiple wounds of the head, neck, chest, and upper extremities.

compound comminuted fractures of the second and third ribs. Another penetrating wound in the right anterior side of the chest at the level of the fourth intercostal space adjacent to the sternum extended downward into the thoracic cavity. Three penetrating wounds in the posterior left side of the chest measured 1 cm. in diameter, 3 x 5 cm. and 1 x .3 cm. A laceration, 2 x 5 cm., was present in the top of the right shoulder. The track passed through comminuted fractures of the proximal end of the humerus and lateral angle of the scapula.

Case No. 907.—T. Sgt., 755th Tank Battalion, 31 Oct. 1944; missile: high explosive; multiple wounds in the head, chest, and right upper extremity (fig. 248). There was a through-and-through wound in the vault of the skull with the entrance, 2 x 3 cm., in the left posterior parietal area and the wound of exit, 5 cm. in diameter, in the right posterior

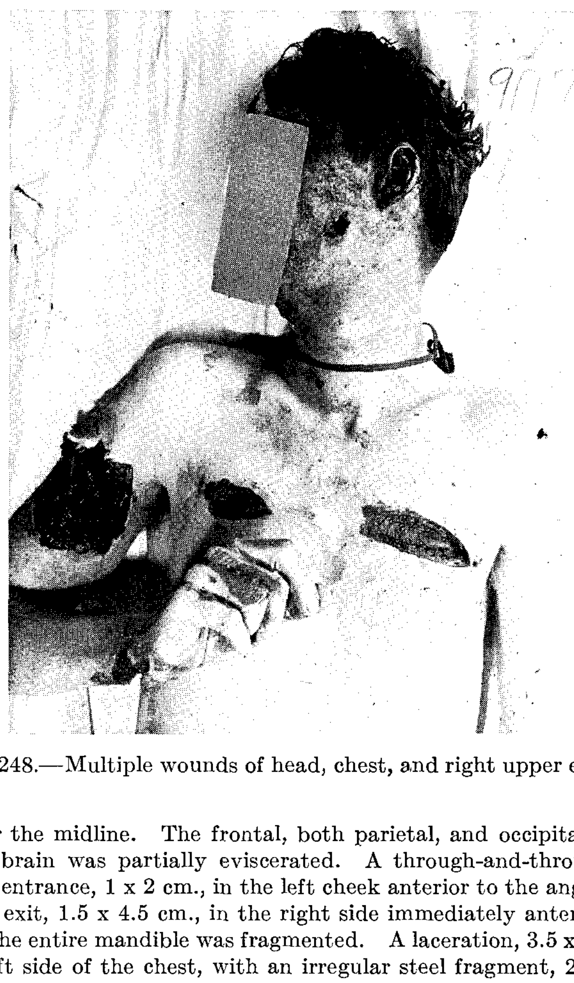

FIGURE 248.—Multiple wounds of head, chest, and right upper extremity.

parietal area near the midline. The frontal, both parietal, and occipital bones were fragmented and the brain was partially eviscerated. A through-and-through wound in the lower jaw had its entrance, 1 x 2 cm., in the left cheek anterior to the angle of the mandible and its wound of exit, 1.5 x 4.5 cm., in the right side immediately anterior to the angle of the mandible. The entire mandible was fragmented. A laceration, 3.5 x 7 cm., was present in the anterior left side of the chest, with an irregular steel fragment, 2.3 x 1.2 x 0.6 cm., embedded in one end of it. Another laceration, 2 x 5 cm., was found in the right anterior side of the chest at the same level. A lacerated wound, 8 x 11 cm., was seen in the middle of the right arm, anteriorly. A penetrating wound, 3 x 5.5 cm., located proximal to the right wrist in the ventral surface, exposed a compound comminuted fracture in the distal end of the ulna.

Case No. 254.—Pvt., 437th Antiaircraft Artillery (Air Warning) Battalion, 4 July 1944; missile: landmine; multiple wounds in the head, chest, abdomen, right upper extremity, and both lower extremities (fig. 249). Many large severe penetrating wounds were found in the ventral surface of the body. There was complete mutilation of the head with total loss of the brain. A large opening in the left side of the chest revealed multiple fractures of the ribs. A large penetrating wound in the right upper quadrant of the abdomen had intestine eviscerated through it. The right arm was mutilated. Numerous small and large penetrating wounds were present in both thighs and legs and there was a compound comminuted fracture of the left femur in the distal third.

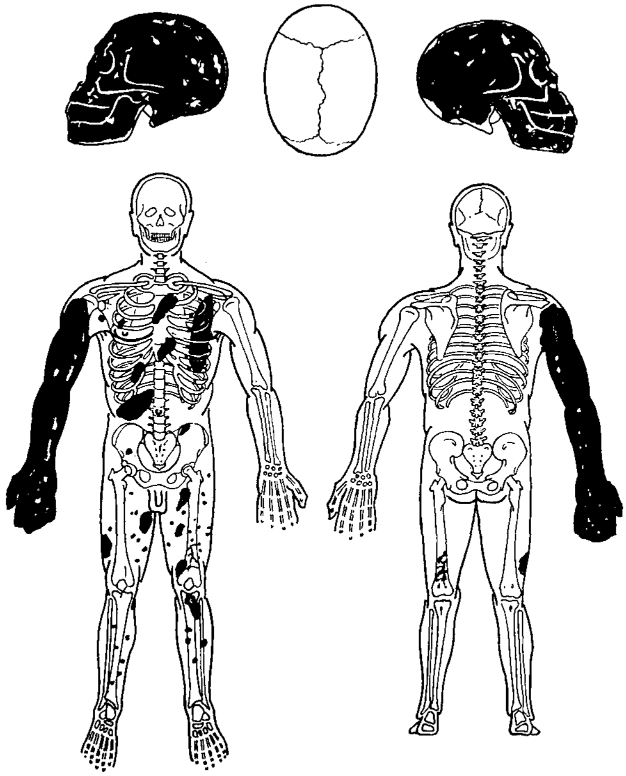

FIGURE 249.—Multiple wounds of head, chest, abdomen, right upper extremity, and both lower extremities.

Case No. 655.—Pfc., 19th Engineer Battalion, 15 Oct. 1944; missile: shell fragments; multiple wounds in the chest, abdomen, left upper and both lower extremities (fig. 250 A and B). A penetrating wound, 1 cm. in diameter, was present in the anterior right side of the chest at the level of the second rib. Three other penetrating wounds were found in the anterior aspect of the chest, each 5 mm. in diameter. A laceration, 10 x 13 cm., was located in the lateral left side of the chest without penetration of the thorax. A penetrating wound, 2 x 3 cm., entered the abdominal cavity in the mid epigastrium. A mutilating wound, 10 x 20 cm., in the left ventral arm revealed a compound comminuted fracture through the middle third of the humerus. A through-and-through wound in the left proximal forearm had a ventral opening, 5 x 8 cm., and a dorsal opening, 6 x 12 cm. There was laceration of the muscles and a compound comminuted fracture of the radius in the track.

FIGURE 250 A and B.—Multiple wounds of chest, abdomen, and upper and lower extremities.

Three other penetrating wounds in the left arm and forearm varied from 5 mm. to 5 cm. in diameter. A penetrating laceration, 20 x 30 cm., was located in the left anterior and medial thigh; a comminuted fracture of the femur was visible in this wound. Mutilating penetrating wounds were present in both knees, with compound comminuted fractures of the tibia, fibula, patella, and femur in the left leg and compound comminuted fractures of the same bones, except the patella, in the right leg.

Case No. 663.—Pfc., 351st Infantry, 15 Oct. 1944; missile: shell fragments; multiple wounds in the neck and chest (fig. 251) and left lower extremity. A mutilating wound,

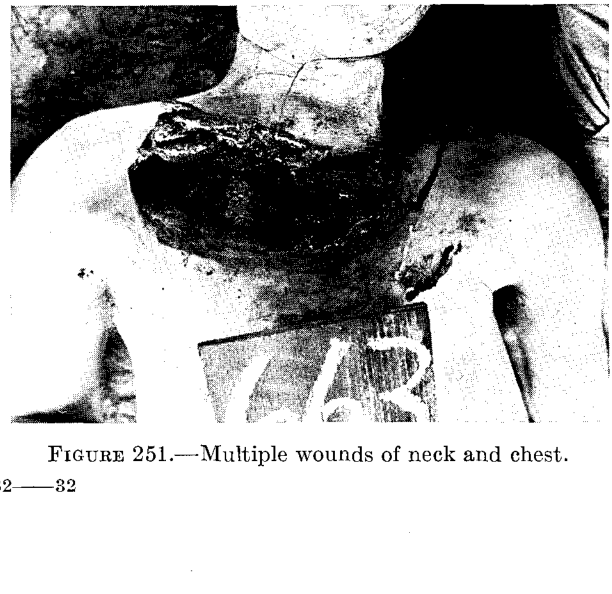

FIGURE 251.—Multiple wounds of neck and chest.

11 x 21 cm., was present in the superior anterior side of the chest and the lower portion of the neck. There were compound comminuted fractures of both clavicles and of the first and second ribs on both sides in the wound. The right lung was visible through the opening. A superficial through-and-through wound in the left anterior distal thigh had a lateral opening, 1.5 x 2 cm., and a medial opening, 1.7 x 2 cm.

FIGURE 252 A and B.—Multiple wounds of head, neck, chest, and upper and lower extremities.

Case No. 731.—2d Lt., 755th Tank Battalion, 18 Oct. 1944; missile: high explosive; multiple wounds in the head, neck, chest, and both upper and left lower extremities (fig. 252 A and B). A penetrating wound, 1.5 cm. in diameter, entered the skull in the midline through the coronal suture. There was slight evisceration of the brain through this opening. A lacerated penetrating wound, 2.5 x 7 cm., in the left cheek involved the lower and upper lips. Compound comminuted fractures of the mandible and maxilla were visible in this wound. A penetrating wound, 1.5 x 2 cm., entered the right cheek inferior to the zygomatic arch. A penetrating wound, 1 cm. in diameter, entered the base of the right side of the neck. A mutilating wound, 9 x 11 cm., was found in the posterior side of the right shoulder; there were fractures in the head of the humerus, the scapula, clavicle and first four ribs, and an opening into the thoracic cavity. A mutilating wound, 11 x 23 cm., in the anterior left side of the chest extended from the second intercostal space to the lateral left thoracic margin, accompanied with fractures of the fourth, fifth, and sixth costal cartilages and exposure of the pericardium but no penetration of the pericardial sac. A superficial laceration, 3 x 6 cm., was located in the left antecubital space. A lacerated wound in the left thumb and left fourth and fifth digits exposed compound comminuted fractures in the metacarpals and the first and second phalanges of the fourth and fifth digits. A deep laceration, 17 x 35 cm., in the left posterior and medial thigh extended from the popliteal space to the crease of the buttock. The left femur was not fractured. A penetrating wound, 1.5 cm. in diameter, entered the left anterior superior thigh. Four penetrating wounds were present in the left anterior leg and thigh. They varied from 1 cm. to 1.5 cm. in diameter.

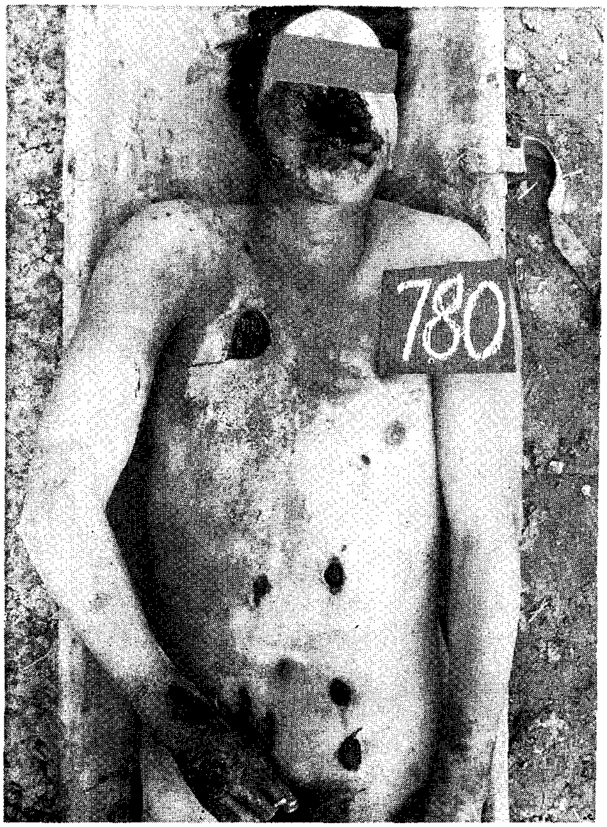

FIGURE 253.—Multiple wounds of head, neck, chest, abdomen, and right upper extremity.

Case No. 780.—Pfc., 760th Tank Battalion, 20 Oct. 1944; missile: shell fragments; multiple wounds in the head, neck, chest, abdomen, right upper extremity (fig. 253), and both lower extremities. A lacerated penetrating wound, 3 x 10 cm., in the face involved the right cheek, upper and lower lips, and part of the chin. It opened into the right maxillary sinus and passed through the right lower jaw. The right ear was lacerated adjacent to a penetrating wound, 2 x 3 cm., in the right mastoid process. The track extended downward and medially behind the sternomastoid muscle. A wound, 1 cm. in diameter, penetrated the neck above the middle third of the right clavicle. The track passed downward and medially and entered the thorax above the first rib. A wound, 4 cm. in diameter, entered the thoracic cavity in the anterior right side of the chest at the level of the first and second ribs, through compound comminuted fracture in the second and third ribs. The track penetrated in a downward medial direction. Six wounds in all four quadrants of the abdomen varied from 1 x 2 cm. to 2.5 x 3.5 cm. None of these wounds entered the abdominal cavity. A mutilating laceration in the right lateral distal forearm was located adjacent to the wrist. A compound comminuted fracture in the distal end of the radius was seen in this wound. A wound, 2 cm. in diameter, penetrated the left anterior superior thigh. An irregular steel fragment, 2 x .8 cm., was embedded in this wound. A laceration, 3 x 5 cm., was present in the medial side and dorsum of the right foot. Compound comminuted fractures were visible in the first and second matatarsal bones.

FIGURE 254.—Multiple wounds of pelvis, lower extremities, and genitalia.

Case No. 831.—Pfc., 401st Antiaircraft Artillery, 27 Oct. 1944; missile: shell fragments; multiple wounds in the head, chest, pelvis, both upper and both lower extremities, and genitalia (fig. 254). There was a through-and-through wound in the head. The probable wound of entrance was an opening, 1.3 x 2.5 cm., in the left temple and the point of exit, a wound inside the mouth which perforated the left maxilla. The left superior canine tooth, both premolars, and the first molar were avulsed. A penetrating wound, 2.5 x 3.5 cm., entered the posterior left side of the chest through a compound comminuted fracture in the 11th rib. The left leg was amputated through the pelvis, the perineum, genitalia, and medial side of the right thigh as far down as the knee. The bones of the left side of the pelvis were severely crushed and displaced. The right femur was also fragmented in its lower third. Three penetrating wounds entered the lateral proximal side of the left arm. They measured from 1 x 1.5 cm. to 2.5 cm. There was a comminuted fracture in the middle third of the humerus. Three lacerated open wounds were present in the left mid forearm revealing compound comminuted fractures in both bones. The left hand and wrist was severely mutilated. Several small wounds entered the right wrist. Numerous penetrating lacerations were found in both buttocks.

FIGURE 255.—Multiple wounds of the head, neck, chest, abdomen, and upper extremities.

Case No. 882.—Sgt., 351st Infantry, 30 Oct. 1944; missile: shell fragments; multiple wounds (fig. 255) in the head, neck, chest, abdomen, pelvis, and both upper and both lower extremities. A superficial laceration, 1 x 5 cm., was present in the right side of the forehead. A wound, 3 x 3 cm., entered the anterior side of the neck in the midline, severing the trachea inferior to the larynx. A through-and-through wound in the abdomen had the wound of entrance, 6 x 12 cm., located in the left posterior flank and the wound of exit, 20 x 20 cm., in the left upper quadrant. There was partial evisceration of the intestine through the larger wound, which extended superficially into the left lower thorax. Other penetrating wounds were located in the left superior axillary margin, anterior left shoulder, left inguinal area, left anterior forearm adjacent to the elbow, where all three bones of the arm were comminuted in the wound, right antecubital space, where a compound comminuted fracture was visible in the distal end of the humerus, right anterior superior thigh, left anterior mid thigh and both anterior mid-legs, with compound comminuted fractures in both bones of both legs. The distal end of the left femur was also comminuted.

FIGURE 256.—Single wound of neck. A. Wound of entrance. B. Wound of exit.

Case No. 904.—S. Sgt., 361st Infantry, 31 Oct. 1944; missile: high explosives; multiple wounds (two) in the neck (fig. 256) and left lower extremity. There was a through-and-through wound in the neck with the wound of entrance, 3 x 4 cm., in the left anterior side, where it passed through the body of the sternomastoid muscle. The wound of exit, 3 x 6.5 cm., was found in the midline posteriorly at the base of the skull. Fractures, at the site of exit, extended into the spinal canal through the third and fourth cervical vertebras. A lacerated wound, 1 x 1.5 cm., in the medial side of the left knee had an irregular steel fragment, 2 x 1.6 x .5 cm., embedded in it.

FIGURE 257.—Multiple wounds of abdomen, pelvis, and upper and lower extremities.

Case No. 929.—T5g., 532d Antiaircraft Artillery (Air Warning) Battalion, 3 Nov. 1944; missile: shell fragments; multiple wounds (fig. 257) in the head, neck, chest, abdomen, pelvis, and both upper and lower extremities. There were many lacerated penetrating wounds present on the anterior surface of the body, including both arms and both thighs, the chest, abdomen, face, and neck; the wounds varied in size up to 4 x 6 cm., which was the measurement of a wound located in the anterior superior margin of the left axilla. There was an avulsive wound in the right lower quadrant of the abdomen which extended from a point midway between the symphysis pubis and the thoracic margin into the right anterior mid thigh. Numerous loops of small intestine were eviscerated through the upper extremity of the wound. There was a compound comminuted fracture in the proximal third of the shaft of the right femur. The pelvis was not definitely fractured. The right leg was amputated through the middle third. The distal portion was attached by strips of skin. There was essential traumatic amputation of the left leg through the knee joint. The distal end of the femur was shattered; the severely mutilated distal portion of the leg was attached by a segment of skin; lacerations extended into the medial mid thigh. A lacerated wound, 6 x 10 cm., was present in the dorsum of the left wrist, with mutilation of the third, fourth, and fifth digits of the left hand and fragmentation on the proximal phalanges of all three digits. Compound comminuted fractures were found in both bones of the left forearm in their distal thirds.

CHAPTER VII

Study of Fifth U.S. Army Hospital Battle Casualty Deaths[1]

Howard E. Snyder, M.D., and James W. Culbertson, M.D.

From 1 January 1944 until the surrender of the German armies in Italy on 2 May 1945 (the period covered in this study), 91,631 American soldiers serving in the Fifth U.S. Army were killed or wounded in action (table 120). Of this total, 16,648 (18.2 percent) died on the battlefield or before reaching a medical installation; 11,959 (13 percent) were treated and returned to duty from the division area (fig. 258). Of the remaining 63,024 (68.8 percent) who were admitted to Fifth U.S. Army hospitals (fig. 259), only 1,631 (1.8 percent) died after their admission. Records of 1,411 (86.47 percent) of these hospital battle casualty deaths were available for this study. In addition, the records of 39 casualties who were DOA (dead on arrival) at a hospital were utilized in many sections of this report. Gross post mortem findings formed a part of 733 of these records (table 121). Microscopic autopsy reports were received on 349. Most of the clinical records were fairly complete,

TABLE 120.—*Distribution of 91,631 Fifth U.S. Army casualties in Italy, from 1 January 1944 to 2 May 1945, by category*

Category	Number of casualties	Percent of casualties
Killed in action	16, 648	18. 2
Wounded in action:		
Hospitalized, DOW (died of wounds)	1, 631	1. 8
Hospitalized, lived	61, 393	67. 0
Returned to duty without hospitalization	11, 959	13. 0
Total	91, 631	100. 0

[1] The original three-volume report on which this chapter is based was submitted as a comprehensive survey and partial analysis of available information on 1,450 fatally wounded American soldiers. There has been a partial attempt to consolidate and interpret some of the findings, but there are still many lessons which may be drawn from this study.

Brig. Gen. (later Maj. Gen.) Joseph I. Martin, Surgeon, Fifth U.S. Army, at the time the study was started, encouraged and helped make possible the report. Col. Charles O. Bruce, MC, the Fifth U.S. Army surgeon during the latter months of the study, furnished needed advice. Maj. Richard A. Morrissey, SnC, statistician in the Fifth U.S. Army surgeon's office was a source of great encouragement.

To the cited personnel, as well as to the many individuals who have not been mentioned, we express sincere appreciation for their unselfish contributions.—H. E. S. and J. W. C.

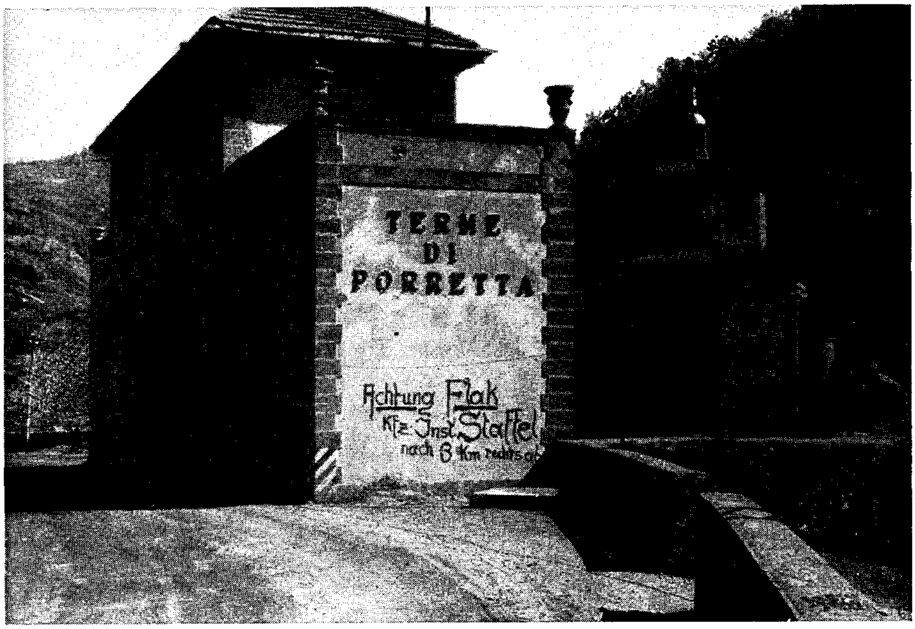

FIGURE 258.—Building occupied by field hospital platoon and four surgical teams, Porretta, Italy.

but, in some, much desirable information was missing. However, most of the autopsies were performed by the operating surgeons already engaged in the arduous surgical tasks associated with an offensive, and the records are a tribute to the scientific zeal of the surgeons working in the Fifth U.S. Army hospitals.

TABLE 121.—*Post mortem studies available and total hospital battle casualty deaths studied, during survey period, 1 January 1944–2 May 1945*

Period	Gross findings available		Microscopic reports available		Total number of hospital battle casualty deaths studied [1]
	Number	Percent	Number	Percent	
1944					
January–March	171	32. 3	37	7. 0	529
April–July	254	52. 7	119	24. 7	482
August–December	180	63. 4	99	34. 9	284
1945					
January–May	128	82. 6	94	60. 6	155
Total	733	50. 6	349	24. 0	1, 450

[1] Includes records of 39 casualties who were DOA at a hospital.

FIGURE 259.—95th Evacuation Hospital, Monghidoro, Italy.

It may be assumed that the 1,411 hospital battle casualty deaths studied are truly representative of the total of 1,631 who (according to MTOUSA MD Form 86f) died in Fifth U.S. Army hospitals. Beginning with 1 January 1944, General Martin requested submission of a complete record on all battle casualties dying in Fifth U.S. Army hospitals. From 1 January 1944 to 2 May 1945, the Adjutant General's "Wound Classification Report" submitted by the hospitals listed 58,677 battle casualty admissions and 1,562 battle casualty deaths in hospitals. These figures are lower than those reported on the MTOUSA MD Form 86f. From the latter, the figure for battle casualty hospital admissions is 63,024 and for battle casualty hospital deaths, 1,631. These larger figures have been used in setting 86.5 percent as the portion studied of all the hospital battle casualty deaths and have been correspondingly reduced when calculating percentage mortalities. In calculating percentages of total battle casualties or of battle casualty hospital admissions, by period, correction has been made for the percentage of cases studied during each period (table 122).

The Adjutant General's figures and the MTOUSA MD Form 86f include the injured in action as well as the WIA and the KIA casualties. Of the deaths studied, only a few who had crush injuries might be regarded as injured rather than as wounded in action. All of the casualties (20) due to crush injuries resulted from falling stones or bricks set in motion by the explosion of

TABLE 122.—*Correction of total battle casualty admission figures to agree with proportion of total deaths analyzed, by survey period, 1 January 1944–2 May 1945*

Survey period	Battle casualty deaths				Battle casualty admissions [1]	
	Reported [1] (number)	Studied [2]			Un-corrected (number)	Corrected (number)
		Number	Percent	Correction factor		
1944						
January–March	570	522	91. 6	8. 4	14, 498	13, 282
April–July	542	466	86. 0	14. 0	23, 111	19, 876
August–December	332	275	83. 0	17. 0	16, 221	13, 464
1945						
January–May	187	148	79. 2	20. 8	9, 194	7, 282
Total	1, 631	1, 411	86. 5	13. 5	63, 024	53, 904

[1] Data obtained from MTOUSA MD Form 86f.
[2] Excludes records of 39 casualties who were DOA at a hospital.

an enemy shell, and most of these casualties had wounds in addition to the crush injury. It may be said, then, that the deaths studied represent a considerably larger percentage of WIA casualties who died than is indicated by the percentage of 86.5 percent which is based upon the total (1,631) of wounded and injured in action who died in Fifth U.S. Army hospitals during the period studied. The breakdown of injured in action and wounded in action is not available either for hospital battle casualty admissions or for the total resulting from the sum of the Adjutant General's figures on wounded in action plus killed in action.

The 39 records of battle casualties DOA at a hospital comprise all the records submitted on this class of deaths. Statistics are not available to determine their percentage of the entire group of DOA's. Most of them were unquestionably patients who, when seen by the last medical officer, were expected to reach the hospital alive. The DOA group has been included in the tables on wound classification and causes of death and, in many instances, has been singled out for individual study as compared to the group of casualties who died shortly after admission, before anesthesia, during anesthetic induction, during primary surgery, and after primary surgery. The cases have not been included in tables dealing with hospital battle casualty deaths or in any of the percentage tables based on hospital battle casualty admissions or the total of wounded in action plus killed in action.

The information recorded in the tables of this report was first recorded in code form so that it might be transferred to machine records cards. Study of the cases and the primary recording of these data consumed the entire time of Capt. (later Maj.) James W. Culbertson, MC, (fig. 260), for a period of a little

FIGURE 260.—Capt. James W. Culbertson, MC, (right) obtaining information from hospital personnel concerning battle casualties.

over 3 months. Col. Howard E. Snyder, MC, (fig. 261) then studied each case and checked the recorded data.[2] Each item was carefully weighed, matters calling for opinion were discussed, and all questionable data were recorded as questionable. The completed machine records cards were checked by hand for accuracy. Colonel Snyder and Captain Culbertson, with their clerical assistants, did all machine counting and recording of data. Many checks were made on the validity of the machine tabulations. It is considered that the margin of error in this method was no greater than, if as great as, the personal error in manual counting.

REGION, TYPE, AND DISTRIBUTION OF WOUNDS

Table 123 lists the general breakdown of the 1,450 casualties as related to hospital admission, anesthesia, and surgery. With experience and improvement in the preparation of battle casualties for surgery, the number of those dying before anesthesia decreased throughout the period covered in the report. When one compares the distribution of hospital deaths during the various time

[2] More data were accumulated than are presented in this chapter. In the original report, figures on timelags are available in all cases in which the information was in the record. Studies on all cases with nephropathies, fat embolisms, shock, thoracoabdominal wounds have been made. These studies are comparable in scope to that study on cases with intra-abdominal wounds which is presented in this report. It is hoped that the statistical information in the complete preliminary report will be of value to those studying and writing upon war surgery.—H. E. S. and J. W. C.

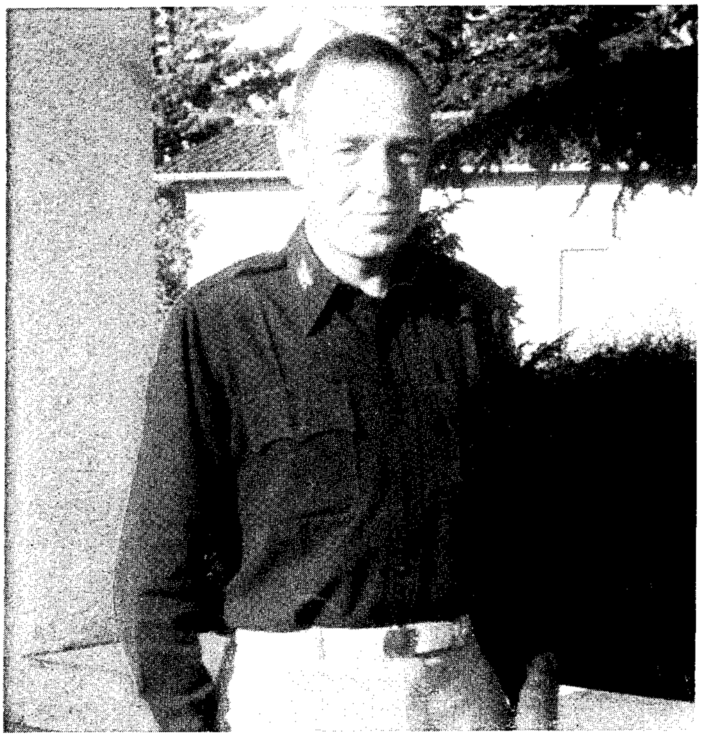

FIGURE 261.—Col. Howard E. Snyder, MC, Surgical Consultant, Fifth U.S. Army, at the time the original report was compiled.

periods to the total hospital battle casualty admissions (table 124), there is a consistent reduction in the percentage of those dying before, during, and after anesthesia. Casualties at the Anzio beachhead were included in the first two periods of the survey (January–March 1944; April–July 1944) and unquestionably increased the percentage of those dying before anesthesia and the total hospital battle casualty mortality in the first two periods. The reduction in the latter mortality figure from 3.9 percent in the first period to 2.0 percent in the last is dependent on more than the Anzio casualties. The reduction in the percentage of those dying before anesthesia is in part due to the general adoption of improved methods of resuscitation and to a more available supply of blood. A hospital battle casualty mortality rate is influenced not only by the hospital's proximity to the battlefront but also by the quality of care administered the wounded who reach it alive.

Morrissey has called attention to the direct relationship of the percentage mortality of battle casualties admitted to hospitals, the percentage mortality of battle casualties admitted to hospitals and dying before anesthesia, and the percentage hospital battle casualty deaths comprised of the total who die of wounds (includes KIA) (table 125). He has shown that the latter percentage varies widely. At Anzio, 16 percent of all battle casualty deaths occurred in hos-

TABLE 123.—*Distribution of 1,450 deaths*[1] *as related to hospital admission, anesthesia, and surgery, during survey period, 1 January 1944–2 May 1945*

Survey period	Dying on admission[2]		Died before anesthesia[3]		Died during anesthetic induction		Died during primary surgery		Died after primary surgery		Total deaths
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
1944											
January–March	27	5. 2	157	30. 1	8	1. 5	20	3. 8	310	59. 4	522
April–July	27	5. 8	108	23. 2	3	. 6	25	5. 4	303	65. 0	466
August–December	12	4. 4	48	17. 4	4	1. 5	19	6. 9	192	69. 8	275
1945											
January–May	8	5. 4	24	16. 2	1	. 7	11	7. 4	104	70. 3	148
Total	74	5. 3	337	23. 9	16	1. 1	75	5. 3	909	64. 4	1, 411

[1] Excludes 39 DOA casualties. Their distribution was as follows: For the January–March 1944 period, 7; for April-July 1944, 16; for August-December 1944, 9; and for January–May 1945, 7.
[2] Lived less than an hour.
[3] Excludes those dying on admission.

TABLE 124.—*Percent of 1,411 hospital deaths studied to total battle casualty hospital admissions (53,904), during survey period, 1 January 1944–2 May 1945*

Survey period	Hospital deaths[1]			Battle casualty hospital admissions[2]			
	Total studied	Before anesthesia[3]	During anesthesia or surgery[4]	Total	Died before anesthesia	Died during anesthesia or surgery	Died in Army hospitals
1944	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*
January–March	522	35. 3	5. 3	13, 282	1. 39	0. 21	3. 9
April–July	466	29. 0	6. 0	19, 876	. 68	. 14	2. 3
August–December	275	21. 8	8. 4	13, 464	. 44	. 17	2. 0
1945							
January–May	148	21. 6	8. 1	7, 282	. 44	. 16	2. 0
Total	1, 411	29. 1	6. 4	53, 904	. 75	. 16	2. 6

[1] Excludes 39 DOA casualties.
[2] Corrected to allow for percentage of deaths not studied during each period. (See table 122.)
[3] From table 123, includes those dying on admission.
[4] From table 123.

pitals (hospital mortality, 5.7 percent). In May 1944, 4.21 percent of all battle casualty deaths occurred in hospitals (hospital mortality, 1.7 percent). In June 1944, 15 percent of all battle casualty deaths were in hospitals (hospital mortality, 2.8 percent). In October 1944, 7.65 percent of all battle casualty deaths were in hospitals (hospital mortality, 2.1 percent). When evacuation of the wounded to the forward hospital (fig. 262) is easily accomplished,

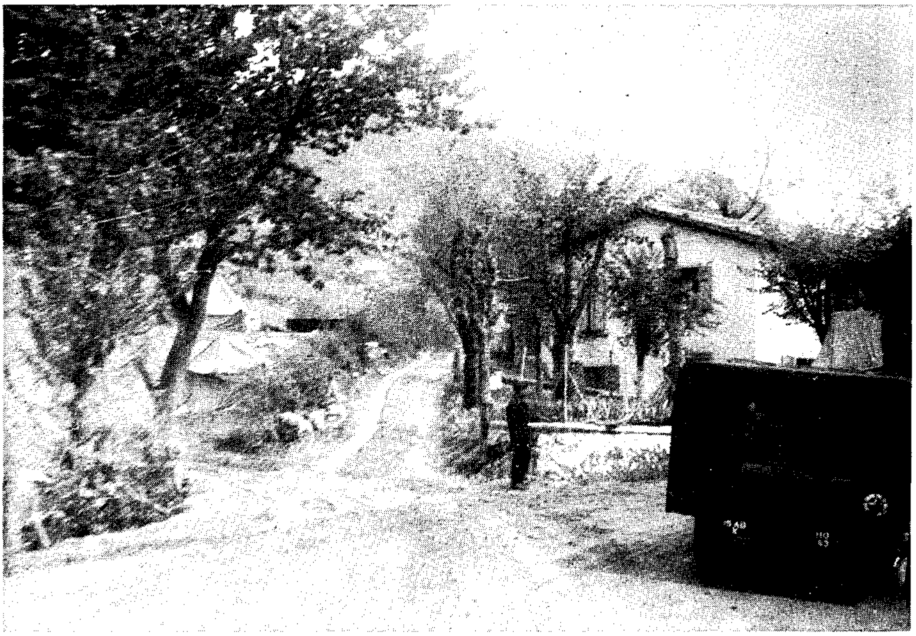

Figure 262.—Location of field hospital platoon used as a forward surgical unit before the breakthrough into the Po Valley.

the hospital mortality rises. Thus, hospital mortality tends to vary inversely with the percentage who are killed in action or who die of wounds before reaching a hospital. However, as is shown in table 125, there has been a steady, gradual decrease in the percentage which deaths occurring during and after surgery comprise of total battle casualty deaths. Table 124 shows a slight increase throughout the four periods in the percentage which deaths during surgery comprise of the deaths studied but a decrease in the percentage these deaths comprise of battle casualties admitted to hospitals.

The simple classification of cases by region of principal wound in table 126 is presented for comparison with similar tables on hospital battle casualty admissions and deaths which were available for all of the Tunisian, Sicilian, and Italian campaigns.

Table 127 lists battle casualty hospital deaths according to principal wound groups. It was found that in only 33.3 percent of the casualties studied were the wounds limited to one of the wound groups listed in this table, and 66.7 percent of the casualties had wounds involving multiple regions of the body. Many of the 33.3 percent had multiple wounds, but these wounds were limited to only one of the anatomic regions.[3]

[3] (1) A more detailed breakdown of the cases listed in table 127 is presented in tables 1 and 2, appendix D (p. 807). Table 1 presents the distribution of associated wounds as related to the region of the principal wound; table 2 presents the regional distribution of principal and associated wounds with the number of cases exhibiting each. (2) A further clarification of the three wound classes in table 127, involving intrathoracic, thoracoabdominal, and combined intra-abdominal and intrathoracic wounds, is presented in appendix E (p. 811).

TABLE 125.—*Demonstration of effect of increased efficiency of evacuation from forward areas on hospital mortality (an increase) and the remaining favorable trend after exclusion of those cases* [1] *dying before anesthesia*

Category	January–March 1944	April–July 1944	August–December 1944	January–May 1945
Killed, wounded, and injured in action____number__	24, 351	32, 026	22, 469	12, 556
Killed in action plus died of wounds [2]_______do____	5, 042	6, 366	4, 234	2, 506
Mortality of the killed, wounded, and injured in action____percent__	20. 70	19. 88	18. 84	19. 96
Battle casualties admitted to hospitals____number__	14, 498	23, 111	16, 221	9, 194
Battle casualties dying in hospitals__________do____	570	542	332	187
Mortality of battle casualties admitted to hospitals____percent__	3. 94	2. 34	2. 05	2. 04
Total battle casualty deaths dying in hospitals ____percent__	11. 3	8. 5	7. 8	6. 8
Hospital battle casualty deaths who died before anesthesia____percent__	35. 3	29. 0	21. 8	21. 6
Hospital battle casualty deaths who died after reaching anesthesia____percent__	7. 3	6. 2	6. 14	5. 3
Total killed, wounded, and injured in action who died after reaching anesthesia____percent__	1. 515	1. 200	1. 160	1. 050

[1] A variable quantity influenced by conditions affecting efficiency of evacuation to hospitals as well as by professional care before and after admission.
[2] Does not include those few deaths which occurred in base hospitals.

Source: History of Fifth Army Medical Service, 1945. [Official record.]

TABLE 126.—*Distribution of battle casualty hospital deaths (1,450 cases), by region of principal wound*

Region of principal wound	Number of cases	Percent of cases
Abdomen	543	37. 4
Head	297	20. 5
Chest	277	19. 1
Lower extremity	145	10. 0
Spine	27	1. 9
Neck	25	1. 7
Upper extremity	14	. 9
Face and jaws	8	. 6
Unclassified multiple wounds	114	7. 9
Total	1, 450	100. 0

Table 127 may be compared with the distribution of wounds among all battle casualties admitted to Fifth U.S. Army hospitals during the period of 1 August 1944 to 2 May 1945 (table 128). Intra-abdominal wounds comprise only 2.84 percent of battle casualties admitted to a hospital but 20 percent of them died and these comprise 28.1 percent of all hospital battle casualty deaths.

TABLE 127.—*Distribution of battle casualty hospital deaths (1,450 cases), by principal wound*

Principal wound[1]	Total cases		Cases without associated wounds	
	Number	Percent	Number	Percent
Intra-abdominal [1]	408	28. 1	131	32. 1
Intracranial	297	20. 5	138	46. 5
Thoracoabdominal [2]	212	14. 6	98	46. 2
Intrathoracic [2]	138	9. 5	37	26. 8
Lower extremity, with bone involvement	[3] 114	7. 8	[4] 49	43. 0
Unclassified, multiple wounds	114	7. 8		
Combined intra-abdominal and intrathoracic [2]	59	4. 1	7	11. 9
Lower extremity, soft tissue only	31	2. 2	14	45. 2
Intravertebral	27	1. 9	1	3. 7
Cervical	25	1. 0	5	20. 0
Upper extremity, with bone involvement	[5] 10	. 7	2	20. 0
Maxillofacial, with bone involvement	8	. 6	1	12. 5
Upper extremity, soft tissue only	4	. 3		
Abdominal wall	3	. 2		
Total	1, 450	100. 0	483	33. 3

[1] A more detailed classification is listed in appendix D, p. 807.
[2] A more detailed classification is listed in appendix E, p. 811.
[3] Includes 43 traumatic amputations.
[4] Includes 17 traumatic amputations.
[5] Includes 2 traumatic amputations.

TABLE 128.—*Distribution of 20,747 American battle casualties admitted to Fifth U.S. Army hospitals, 1 August 1944–2 May 1945, by principal wound group*

Principal wound	Percent of all battle casualty admissions	Percent that died
Intra-abdominal	2. 84	20. 0
Thoracoabdominal plus combined intra-abdominal and intrathoracic	1. 66	20. 4
Superficial abdominal	. 74	. 0
Intrathoracic	4. 64	7. 8
Superficial thoracic	3. 73	. 2
Intracranial	1. 95	26. 00
Scalp	3. 77	. 0
Lower extremity:		
Soft tissue and bone	9. 35	1. 74
Soft tissue only	32. 48	. 25
Upper extremity:		
Soft tissue and bone	6. 25	. 28
Soft tissue only	19. 30	. 02
Neck	2. 07	. 87
Spine	. 94	7. 10
Maxillofacial:		
Soft tissue only	4. 68	. 29
Bone and soft tissue	1. 22	1. 50
Eye and ear	2. 00	. 00
Other	2. 30	. 55

NOTE.—0.0 indicates a rate of more than zero but less than 0.05, and 0.00 a rate of more than zero but less than 0.005.

The intra-abdominal, intrathoracic, thoracoabdominal, combined intra-abdominal and intrathoracic, and intracranial wounds comprise only 11.09 percent of hospital battle casualty admissions, and yet they account for 76.8 percent of all hospital battle casualty deaths. Table 129 relates the 1,411 hospital battle casualty deaths to the total hospital battle casualty admissions during the survey period.

TABLE 129.—*Hospital battle casualty deaths listed as to principal wound with percentage of hospital battle casualty admissions*

Principal wound	Number of deaths [1]	Percent of total [2] hospital battle casualty admissions (53, 904)
Intra-abdominal	402	0. 745
Intracranial	288	. 534
Thoracoabdominal	210	. 389
Intrathoracic	131	. 241
Lower extremity (bone involvement)	110	. 204
Unclassified, multiple wounds	106	. 196
Combined intra-abdominal and intrathoracic	57	. 105
Lower extremity, soft tissue only	30	. 055
Intravertebral	27	. 050
Cervical	25	. 046
Upper extremity (bone involvement)	10	. 018
Maxillofacial	8	. 014
Upper extremity, soft tissue only	4	. 007
Abdominal wall	3	. 005
Total	1, 411	2. 61

[1] Does not include 39 DOA casualties.
[2] Figure of total 63,024 admissions corrected to allow for 13.5 percent of hospital battle casualty deaths not studied.

The type of causative agent as related to the principal wound is listed in table 130. Small arms accounted for approximately 15.11 percent of the hospital deaths while high explosive shell fragments (exclusive of mine, boobytrap, and bomb) were identified in 59.38 percent of the cases.

Table 131 correlates the principal wound with the time of death and the hospital admission, anesthesia, and surgery.

TABLE 130.—*Distribution of 1,450 casualties, by causative agent as related to principal wound*

Principal wound	Total casualties	Bullet			High explosive						No record of causative agent	Casualties with—	
		Unclassified	Rifle	Machine-gun	Unclassified	Shell	Mine	Booby-trap	Bomb	Blast		Penetrating wound [1]	Perforating wound [1]
Intracranial	297	19	8	6	37	181	10	------	17	2	17	199	42
Intravertebral	27	2	2	2	2	14	------	------	2	------	3	19	5
Maxillofacial	8	------	------	1	1	4	------	------	------	1	1	4	1
Cervical	25	3	------	2	4	13	1	------	2	------	------	16	1
Intrathoracic	138	20	1	9	12	79	2	------	4	1	10	94	33
Thoracoabdominal	212	35	7	7	11	130	10	------	8	------	4	152	67
Combined intra-abdominal and intrathoracic	59	2	1	------	8	37	4	------	3	2	2	47	11
Intra-abdominal	408	54	11	15	40	254	9	------	12	1	12	287	126
Abdominal wall only	3	------	------	------	------	3	------	------	------	------	------	2	------
Upper extremity:													
Soft tissue only	4	------	------	------	------	2	------	------	------	------	2	3	------
Bone and soft tissue	10	------	------	------	4	6	------	------	------	------	------	5	1
Lower extremity:													
Soft tissue only	31	5	------	1	5	14	2	------	2	1	1	12	7
Bone and soft tissue	114	2	------	2	21	59	19	------	7	------	4	47	21
Unclassified, multiple	114	1	1	------	15	65	13	2	10	2	5	78	17
Total	1, 450	143	31	45	160	861	70	2	67	10	61	965	332

[1] Cases of blast, crush, and mutilating injury could not be classified in this manner, and number is less than total of 1,450.

TABLE 131.—*Distribution of 1,450 battle casualty deaths as related to hospital admission, anesthesia, and surgery, by principal wound*

Principal wound	DOA	Dying on admission [1]	Died before anesthesia [2]	Died during anesthetic induction	Died during primary surgery	Died after primary surgery
Intra-abdominal	6	12	45	8	20	317
Intracranial	9	17	142	--------	6	123
Thoracoabdominal	2	3	20	2	29	156
Intrathoracic	7	13	35	2	8	73
Lower extremity, bone and soft tissue	4	14	18	--------	5	73
Unclassified multiple	8	7	45	2	3	49
Combined intra-abdominal and intrathoracic	2	3	6	1	2	45
Lower extremity, soft tissue only	1	2	5	--------	--------	23
Intravertebral	--------	--------	10	--------	--------	17
Cervical	--------	2	5	--------	2	16
Upper extremity, bone and soft tissue	--------	1	2	--------	--------	7
Maxillofacial	--------	--------	--------	1	--------	7
Upper extremity, soft tissue only	--------	--------	4	--------	--------	--------
Abdominal wall only	--------	--------	--------	--------	--------	3
Total	39	74	337	16	75	909

[1] Lived less than 1 hour.
[2] Excludes the DOA cases and those casualties who lived less than 1 hour.

CAUSES OF DEATH

General Observations

Certain problems were encountered in the classification and arrangement of this material. The Adjutant General of the Fifth U.S. Army and The Adjutant General of the U.S. Army report battle casualty deaths as "killed in action" or "died of wounds" (the latter includes those dying of injuries incurred in action). Hospitals report deaths according to a classification of principal wounds. Generally speaking, all battle casualties who die are said to die of wounds or injuries incurred in action. All of the cases reported in this study may be said to have died either of wounds or of injuries incurred in action against the enemy. Table 132 classifies the cases as to region of primary trauma leading to death. This classification is comparable to those just mentioned. For the purposes of this study, however, such classifications have been deemed inadequate.

A battle casualty who suffers a laceration of the popliteal artery may or may not lose sufficient blood to lead to severe shock, and death. If he does, the primary cause of death according to conventional reports is a wound of

TABLE 132.—*Distribution of battle casualty hospital deaths (1,450 cases) during survey period, 1 January 1944–2 May 1945, by region of primary trauma leading to death*

Region of primary trauma	January–March 1944		April–July 1944		August–December 1944		January–May 1945		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Shock [1]	183	34. 6	192	39. 9	93	32. 7	55	35. 5	523	36. 1
Intracranial	73	13. 7	71	14. 7	48	16. 9	42	27. 1	234	16. 1
Thoracic	45	8. 4	45	9. 4	47	16. 5	21	13. 6	158	10. 9
Abdominopelvic	30	5. 6	59	12. 3	47	16. 5	18	11. 6	154	10. 6
Extremity	32	6. 0	8	1. 7	3	1. 1	2	1. 3	45	3. 1
Spinal	6	1. 1	1	. 2	9	3. 2	3	1. 9	19	1. 3
Miscellaneous (general)	5	. 9	3	. 4	3	. 1			11	. 8
Cervical	1	. 6	1	. 2					2	. 1
Maxillofacial			1	. 2					1	. 1
Undetermined, unclassified	154	29. 1	101	21. 0	34	12. 0	14	9. 0	303	20. 9
Total	529	100. 0	482	100. 0	284	100. 0	155	100. 0	1, 450	100. 0

[1] Generalized conditions involving more than one region.

the posterior aspect of the knee, with laceration of the popliteal artery. For the purposes of this report, the important desideratum in such a case is that the immediate or precipitating cause of death is shock (peripheral vascular failure).

While fully aware of the controversial nature of the subject, the decision was made to include the uncorrected state of shock as an immediate or precipitating cause of death, along with other more specific, standard diagnoses. It may be contended, of course, that such patients actually die of their wounds and the severity of the trauma attending them and that the shock which is present is a syndrome reflecting a profound pathologic alteration of normal hemodynamics and is not an acceptable diagnosis. However, in this study, as just stated, each case has been classified as to primary trauma leading to death (the conventional primary or basic diagnosis), and the liberty of employing the concept of the state of shock as a "diagnosis" for the immediate or precipitating cause of death (the conventional secondary diagnosis) allows for a more complete classification of the causes of death for comparison and study. This sets in relief that important group of cases which succumbed from the gravity of their wounds in a state of uncontrolled shock. It seems that this group of cases is worthy of the special attention afforded by such a classification.

Shock was selected as the immediate cause of death in 523 cases in this series. A special study was made on this group and is presented on page 511. The criteria used in naming shock as an immediate cause of death are discussed there and are apparent in the information tabulated.

"Neural trauma and/or intracranial hemorrhage or clot" was listed as the immediate cause of death in 212 cases and is second on the list of the immediate causes of death, as is shown in tables 133 and 134 and in the tabulation which is to follow. The relative importance as a lethal factor of the brain damage produced by the missile and the damage produced by an expanding intracranial hematoma was often difficult to determine. It seemed unwise, considering the available information and the qualifications necessary for evaluation, to attempt to separate these cases into two groups. It may be mentioned here that only 15 cases in whom the principal wound was intracranial were listed as dying of shock, while 210 were listed as dying of neural trauma or clot. (All 235 cases in these two categories were listed also under the heading "Primary trauma leading to death, intracranial.") Nephropathies were third on the list, and their incidence was relatively constant except during the first 3 months of the period covered by this report. The low incidence at that time may be attributed to failure of recognition and is therefore apparent rather than real.

	Number of cases
Immediate cause of death:	
Shock	523
Neural (brain) trauma and/or intracranial hemorrhage or clot	212
Pigment nephropathy	68
Peritonitis	65
Clostridial myositis	51
Pneumonia	49
Fat embolism	27
Thrombotic embolism	20
Spinal cord trauma	16
Tracheobronchial obstruction:	
Aspirated vomitus	11
Blood and mucus	11
Cerebral ischemia	8
Anesthetic agent	7
Empyema thoracis	7
Intracranial blast trauma alone	5
Cellulitis (extraperitoneal)	4
Myocardial decompensation	4
Coronary occlusion	3
Pulmonary blast trauma alone	3
Respiratory obstruction above trachea	3
Abscess, intra-abdominal	2
Air embolism	2
Infarction of lung	2
Intestinal obstruction	2
Intracranial blast and other trauma	2
Meningitis, intracranial	2
Immediate cause of death—Con.	
Pulmonary blast and other trauma	2
Ventricular arrest	2
Abscess, intracranial	1
Infarction, brain and lung	1
Mediastnial hemorrhage	1
Mediastinitis	1
Meningitis, spinal	1
Pneumonitis	1
Respiratory failure, cause undetermined	1
Sepsis unclassified, abdominal	1
Sepsis unclassified, extremity	1
Septicemia	1
Thoracoabdominal trauma, unclassified	1
Transfusion reaction	1
Other intra-abdominal condition	2
Other intracranial condition	1
Undetermined thoracic condition	12
Undetermined intra-abdominal condition	4
Undetermined abdominal wall condition	1
Undetermined intracranial condition	2
Undetermined, unclassified	303
Total	1, 450

TABLE 133.—*Distribution of 1,450 battle casualty deaths*[1] *during survey period, 1 January 1944–2 May 1945, by cause of death*

Cause of death	January–March 1944		April–July 1944		August–December 1944		January–May 1945		January 1944 through May 1945	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Shock	183	34. 6	194	40. 3	91	32. 0	55	35. 5	523	36. 1
Neural trauma and/or intracranial hemorrhage or clot	65	12. 3	66	13. 7	45	15. 8	36	23. 2	212	14. 7
Nephropathy	9	1. 7	25	5. 2	26	9. 2	8	5. 2	68	4. 7
Peritonitis	13	2. 5	26	5. 4	19	6. 7	7	4. 5	65	4. 5
Clostridial myositis	35	6. 6	11	2. 3	4	1. 4	1	. 6	51	3. 5
Pneumonia	20	3. 8	6	1. 2	17	6. 0	6	3. 9	49	3. 4
Fat embolism	5	. 9	9	1. 9	9	3. 2	4	2. 6	27	1. 9
Thrombotic embolism	5	. 9	12	2. 5	1	. 4	2	1. 3	20	1. 4
Spinal cord trauma	6	1. 1	1	. 2	6	2. 1	3	1. 9	16	1. 1
Tracheobronchial obstruction:										
Aspirated vomitus	3	. 6	1	. 2	3	1. 1	4	2. 6	11	. 8
Blood and mucus	1	. 2	4	. 8	3	1. 1	3	1. 9	11	. 8
Cerebral ischemia	2	. 4	1	. 2	2	. 7	3	1. 9	8	. 6
Others in which immediate cause of death is known	28	5. 3	25	5. 2	24	8. 4	9	5. 9	86	5. 6
Remainder in which immediate cause of death is undetermined, unclassified	154	29. 1	101	20. 9	34	11. 9	14	9. 0	303	20. 9
Total	529	100. 0	482	100. 0	284	100. 0	155	100. 0	1, 450	100. 0

[1] See tabulation on text page 487 for the total list of the immediate causes of death in the 1,450 cases.

In the first survey period, clostridial myositis was the third leading cause of death, the 35 cases comprising 6.5 percent of all deaths, and 0.28 percent of hospital battle casualty admissions. In the last period, it fell to the bottom of the list, with only one death attributed to it, comprising 0.6 percent of the deaths studied, and only 0.01 percent of all battle casualties admitted to hospitals. The educational program concerning clostridial myositis and the study of the problem conducted by Maj. Floyd H. Jergesen, MC, and Lt. Col. F. A. Simeone, MC, coupled with the more complete surgery on all wounds, the more liberal use of blood, and the advent of the extensive use of penicillin were important factors in effecting this striking reduction in mortality and the corresponding reduction in the incidence.

Peritonitis tended to show a slight increase in its percentage of the total battle casualty admissions and a more pronounced increase in its percentage of the deaths studied. There are two factors which may have contributed. First is the reduction in mortality from shock, clostridial myositis, extremity wounds,

TABLE 134.—*Distribution of 1,450 battle casualty deaths, showing percent of the total battle casualty admissions (53,904)* [1] *during survey period, 1 January 1944–2 May 1945, by cause of death*

Cause of death	January–March 1944	April–July 1944	August–December 1944	January–May 1945	January 1944 through May 1945
Shock	1. 38	0. 98	0. 676	0. 750	0. 960
Neural trauma and/or intracranial hemorrhage or clot	. 49	. 35	. 334	. 490	. 390
Peritonitis	. 068	. 126	. 193	. 110	. 125
Clostridial myositis	. 280	. 055	. 030	. 010	. 094
Pneumonia	. 160	. 030	. 126	. 080	. 090
Fat embolism	. 040	. 040	. 067	. 050	. 050
Thrombotic embolism	. 040	. 060	. 010	. 030	. 040
Spinal cord trauma	. 050	. 005	. 050	. 040	. 030
Tracheobronchial obstruction:					
Aspirated vomitus	. 020	. 005	. 020	. 050	. 020
Blood and mucus	. 010	. 020	. 020	. 040	. 020
Cerebral ischemia	. 020	. 005	. 015	. 040	. 015

[1] Corrected to allow for the percentage of hospital battle casualty deaths not studied in each period.

and unclassified wounds in the course of the 17 months covered by the study. This has led to a relative increase in peritonitis deaths, deaths from intracranial wounds, and other wounds or complications, the incidence of which was more or less inevitable. The second factor is the increase in the percentage of autopsies performed which probably accounts for the apparent but slight increase in the number of peritonitis deaths as compared to hospital battle casualty admissions.

The only striking variation in mortality from pneumonia is in the April–July 1944 period, in which pneumonia deaths comprised only 1.2 percent of the deaths studied as compared to the average of 3.4 percent for all four periods. It is the only one of the four periods which did not include winter months.

Tables 135, 136, and 137 compare the region of principal wound, the immediate cause of death, and the region of primary trauma. Attention is directed to the incidence of fat embolism. This diagnosis was not recorded except when microscopic reports indicated large amounts of fat in the pulmonary sections and the record indicated a clinical behavior justifying the diagnosis. It may be noted (table 148) that the diagnosis of fat embolism was evident in 22 additional cases in which it was listed as a contributory condition rather than as the immediate cause of death.

Thrombotic embolism and tracheobronchial obstruction from aspirated vomitus, blood, or mucus appear quite prominently in the leading causes of death. Their relative incidence showed a definite increase and the actual incidence perhaps a slight increase in spite of recognition of their importance and the inauguration of prophylactic measures early in the campaign.

603225v—62——33

TABLE 135.—*Comparison of principal wound with region of immediate cause of death (1,450 cases)*

Anatomic region	Region of principal wound in—		Region of immediate cause of death in—	
	Cases (number)	Percent of cases studied	Cases (number)	Percent of cases studied
Abdominal	543	37. 5	154	10. 6
Intracranial	297	20. 5	234	16. 1
Thoracic	277	19. 1	158	10. 9
Extremity	159	11. 0	45	3. 1
Intravertebral	27	1. 8	19	1. 3
Cervical	25	1. 7	2	. 1
Maxillofacial	8	. 5	1	. 1
Unclassified	[1] 114	7. 9	[2] 303	20. 9
General [3]			11	. 8
Shock			523	36. 1
Total	1, 450	100. 0	1, 450	100. 0

[1] Multiple wounds.
[2] Cause of death undetermined.
[3] More than one region involved by cause of death, excluding shock.

TABLE 136.—*Region of immediate cause of death as related to region of principal wound (1,450 cases)*

Principal wound	Abdominal	Cervical	Extremity	Intracranial	Maxillofacial	Spinal	Thoracic	General [1]	Shock	Undetermined, unclassified
Intracranial	2		3	221		1	15		15	40
Intravertebral						16	4		4	3
Maxillofacial							3		1	4
Cervical	1	2		4			4		11	3
Intrathoracic	3		1	3			37	1	70	23
Thoracoabdominal	25			1	1		20	1	118	46
Combined intra-abdominal and intrathoracic	14			1			7	1	25	11
Intra-abdominal	89		7				39	4	178	91
Abdominal wall only	1						1			1
Upper extremity:										
Soft tissue only	1								2	1
Bone and soft tissue			1					1	3	5
Lower extremity:										
Soft tissue only	5		8			1	3	1	9	4
Bone and soft tissue	8		22	1			15	2	41	25
Unclassified, multiple	5		3	3		1	10		46	46
Total	154	2	45	234	1	19	158	11	523	303

[1] Involving more than one region, a miscellaneous group, excluding shock.

TABLE 137.—*Region of primary trauma leading to death, by period*

Primary trauma	January–March 1944		April–July 1944		August–December 1944		January–May 1945		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Abdominopelvic	124	23. 5	131	27. 2	80	28. 2	33	21. 3	368	25. 4
Intracranial	97	18. 3	81	16. 8	57	20. 1	46	29. 7	281	19. 4
Thoracoabdominal	62	11. 7	74	15. 3	43	15. 1	23	14. 8	202	13. 9
Extremity	83	15. 7	58	12. 0	28	9. 9	9	5. 8	178	12. 3
Unclassified, multiple	83	15. 7	55	11. 4	25	8. 8	12	7. 7	175	12. 1
Thoracic	44	8. 3	49	10. 2	30	10. 5	11	7. 1	134	9. 2
Combined thoracic and abdominal	18	3. 4	17	3. 6	10	3. 5	8	5. 2	53	3. 7
Cervical	8	1. 5	10	2. 1	2	. 7	6	3. 9	26	1. 8
Spinal	7	1. 3	4	. 8	8	2. 8	6	3. 9	25	1. 7
Maxillofacial	1	. 2	3	. 6	1	. 4	1	. 6	6	. 4
Undetermined [1]	2	. 4							2	. 1
Total	529	100. 0	482	100. 0	284	100. 0	155	100. 0	1, 450	100. 0

[1] Record inadequate in description of wounds.

Tables 138 through 149 deal with the total reported incidence of immediate and contributing causes of death. In this report, they are the best source of information regarding the incidence of any one condition. All the figures in the column under "Immediate cause of death" represent evident or confirmed incidence. The figures in the middle column represent both evident and suspected evidence, but in every instance they are separated and properly identified by the index column. The same applies to the total figures in the last column.

TABLE 138.—*Total reported incidence of shock in 1,450 battle casualty deaths*

Etiology or type of shock	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Cardiorespiratory embarrassment plus trauma and hemorrhage	147	135	282
Cardiorespiratory embarrassment plus trauma and hemorrhage plus contamination or sepsis	72	58	130
Contamination or sepsis plus trauma and hemorrhage	120	186	306
Trauma and hemorrhage	182	370	552
Type undetermined	2	1	3
Total	523	750	1, 273

[1] Probably somewhat lower than the actual incidence.

The figures are believed to be lower than the actual incidence inasmuch as they represent only the reported incidence, and inasmuch as the records at times are not complete. The incidence figures on shock are perhaps nearer the actual than most of the other figures, because many indications of the presence of shock may be found in the record when it is present.

TABLE 139.—*Total reported incidence of intracranial conditions in 1,450 battle casualty deaths*

Intracranial condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Abscess	1	10	11
Blast trauma:			
Evident	7	17	24
Suspected		29	29
Cerebral death suspected		57	57
Encephalomalacia		60	60
Fungus, cerebral, septic		2	2
Hygroma		4	4
Ischemia	8	14	22
Meningitis	2	7	9
Trauma and/or hemorrhage, evident, unclassified [2]	212	155	367
Intracranial trauma,[2] unclassified, suspected		16	16
Other	1		1
Undetermined	2		2
Respiratory failure, cause undetermined	1		1
Total	234	371	605

[1] Probably somewhat lower than the actual incidence.
[2] As distinguished from blast trauma.

TABLE 140.—*Total reported incidence of shock in 1,450 battle casualty deaths*

Shock condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Corrected by therapy		339	339
Suspected, not proved		[2] 76	76
Successful correction doubtful		207	207
Uncorrected	523	128	651
Total	523	750	1,273

[1] Probably somewhat lower than actual incidence.
[2] In an additional 128 cases, shock was suspected as being a contributory cause of death.

TABLE 141.—*Total reported incidence of maxillofacial conditions in 1,450 battle casualty deaths*

Maxillofacial condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Trauma		182	182
Hemorrhage		9	9
Respiratory obstruction:			
Due to plugging of airway	1	2	3
Due to edema or hemorrhage		2	2
Sepsis		4	4
Total	1	199	200

[1] Probably somewhat lower than the actual incidence.

TABLE 142.—*Total reported incidence of cervical conditions in 1,450 battle casualty deaths*

Cervical condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Trauma		108	108
Hemorrhage		27	27
Laceration, fatal, carotid, or subclavian artery		[2] 4	4
Respiratory obstruction:			
Due to edema or hematoma	2	10	12
Due to plugging of airway		9	9
Sepsis		3	3
Total	2	161	163

[1] Probably somewhat lower than the actual incidence.
[2] Immediate cause of death, listed as shock.

TABLE 143.—*Total reported incidence of intravertebral conditions in 1,450 battle casualty deaths*

Intravertebral condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Trauma	16	88	104
Hematomyelia		19	19
Hemorrhage		13	13
Meningitis	1	1	2
Transection of cord:			
Complete		[2] 24	24
Partial		11	11
Total	17	156	173

[1] Probably somewhat lower than the actual incidence.
[2] Includes cases from those in whom the immediate cause of death was intravertebral trauma.

TABLE 144.—*Total reported incidence of extremity conditions in 1,450 battle casualty deaths*

Extremity condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Trauma, unclassified	----------	669	669
Clostridial myositis of extremity:			
Evident	[2] 44	[2] 8	52
Suspected	----------	[2] 28	28
Crushing trauma	----------	3	3
Hemorrhage	----------	142	142
Sepsis (not clostridial)	----------	53	53
Sepsis, unclassified	1	----------	1
Frostbite or immersion syndrome	----------	8	8
Total	45	911	956

[1] Probably somewhat lower than the actual incidence.
[2] Also included in clostridial infections (table 147).

TABLE 145.—*Total reported incidence of thoracic conditions in 1,450 battle casualty deaths*

Thoracic condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Trauma, unclassified	----------	176	176
Thoracoabdominal trauma	1	14	15
Combined intra-abdominal and intrathoracic trauma	----------	4	4
Atelectasis:			
Severe	----------	33	33
Slight or moderate	----------	71	71
Blast trauma:			
Evident	5	84	89
Suspected	----------	77	77
Bronchial fistula:			
Evident	----------	21	21
Suspected	----------	5	5
Cardiac trauma:			
Evident	[2] 2	31	33
Suspected	----------	29	29
Continuing intrapleural hemorrhage	----------	8	8
Coronary occlusion	3	----------	3
Crushing trauma:			
Evident	----------	5	5
Suspected	----------	1	1
Dilatation of heart:			
Severe	----------	28	28
Slight or moderate	----------	61	61
Empyema:			
Mild or moderate	----------	17	17
Severe	7	6	13
Suspected	----------	12	12

See footnotes at end of table.

TABLE 145.—*Total reported incidence of thoracic conditions in 1,450 battle casualty deaths*—Continued

Thoracic condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
External hemorrhage from chest wall		2	2
Fat embolism, pulmonary:			
Evident	[3] 27	20	47
Suspected		65	65
Hemopneumothorax:			
Evident		347	347
Suspected		61	61
Hydrothorax:			
Severe		9	9
Slight or moderate		77	77
Infarction of lung	[3] 3	[3] 6	9
Intrapulmonary hemorrhage:			
Mild or moderate		192	192
Severe		68	68
Suspected		36	36
Lung abscess		14	14
Mediastinal edema		5	5
Mediastinal emphysema		16	16
Mediastinal hemorrhage	1	29	30
Mediastinitis	1	4	5
Myocardial decompensation: [4]			
Evident	4	112	116
Suspected		211	211
Other		14	14
Pleural contamination from abdomen, evident		22	22
Pneumonia:			
Mild or moderate		100	100
Severe	49	22	71
Suspected		28	28
Pneumonitis	1	14	15
Pneumothorax without hemothorax		5	5
Pulmonary edema:			
Severe		204	204
Slight or moderate		145	145
Purulent bronchitis		35	35
Subpleural emphysema		5	5
Tension pneumothorax:			
Evident		18	18
Suspected		7	7
Thrombotic embolism, pulmonary:			
Evident	[3] 20	[3] 14	34
Suspected		17	17
Tracheobronchial obstruction:			
Aspirated vomitus	11	21	32
Blood and mucus	11	103	114
Suspected		25	25

See footnotes at end of table.

TABLE 145.—*Total reportod incidence of thoracic conditions in 1,450 battle casualty deaths*—Continued

Thoracic condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Unrepaired wound of diaphragm	----------	26	26
Ventricular arrest	2	----------	2
Undetermined	12	----------	12
Total	160	2, 782	2, 942

[1] Probably somewhat lower than the actual incidence.
[2] Also included with coronary occlusions and raises the total conditions to 160 rather than the 158 as listed in table 136.
[3] Also included with embolism, thrombosis, and infarction (table 148).
[4] Does not include the three cases of coronary occlusion.

TABLE 146.—*Total reported incidence of abdominal conditions in 1,450 battle casualty deaths*

Abdominal condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Abdominopelvic trauma	----------	147	147
Combined intra-abdominal and intrathoracic trauma	----------	4	4
Thoracoabdominal trauma	----------	14	14
Abscess:			
Extraperitoneal	----------	12	12
Intraperitoneal	2	15	17
Adrenal hemorrhage	----------	15	15
Adrenal trauma	----------	8	8
Adynamic ileus:			
Mild or moderate	----------	36	42
Severe	----------	42	42
Suspected	----------	1	1
Blast trauma:			
Evident	----------	26	26
Suspected	----------	20	20
Cellulitis, mural and extraperitoneal	4	20	24
Clostridial myositis of trunk (abdominal):			
Evident	[2] 7	[2] 4	11
Suspected	----------	[2] 10	10
Contamination from hollow viscus	----------	467	467
Crushing trauma:			
Evident	----------	6	6
Suspected	----------	6	6
Evisceration:			
Postoperative	----------	7	7
Preoperative	----------	78	78
Postoperative and preoperative	----------	2	2
Gangrene of bowel:			
Advanced	----------	9	9
Early	----------	13	13
Gastric dilatation	----------	38	38
Hemorrhage, primary	----------	499	499

See footnotes at end of table.

TABLE 146.—*Total reported incidence of abdominal conditions in 1,450 battle casualty deaths*—Continued

Abdominal condition	Immediate cause of death	Contributory or associated condition	Total reported[1] incidence
Hemorrhage, recurrent or delayed	----------	26	26
Hepatic degeneration, toxic	----------	75	75
Hepatitis, epidemic:			
Evident	----------	7	7
Suspected	----------	4	4
Hepatitis, septic, secondary to trauma:			
Evident	----------	18	18
Suspected	----------	18	18
Inflammation of G–I tract	----------	7	7
Intestinal obstruction (mechanical):			
Mild or moderate	----------	8	8
Severe	2	6	8
Suspected	----------	3	3
Leaking suture line	----------	8	8
Nephropathy, pigment:			
Evident	68	31	99
Suspected	----------	8	8
Nephropathy, toxic, degenerative	----------	26	26
Operative wound infection	----------	17	17
Other abdominal condition	2	23	25
Pancreatic:			
Hemorrhage	----------	6	6
Trauma	----------	25	25
Peritonitis:			
Mild or moderate	----------	92	92
Severe	65	48	113
Suspected	----------	63	63
Renal sepsis (parenchymal)	----------	5	5
Renal trauma:			
Evident	----------	127	127
Suspected	----------	11	11
Sepsis, abdominal, unclassified	1	----------	1
Splenic degeneration, toxic	----------	28	28
Splenomegaly	----------	31	31
Unrepaired wound of hollow viscus[3]	----------	33	33
Ureter traumatized or tied:			
Evident	----------	12	12
Suspected	----------	3	3
Urinary tract sepsis	----------	11	11
Undetermined abdominal wall condition	1	----------	1
Undetermined intra-abdominal condition	4	----------	4
Undetermined: contamination and/or hemorrhage suspected	----------	86	86
Total	154	2, 365	2, 521

[1] Probably somewhat lower than the actual incidence.
[2] Also reported with clostridial myositis (table 147).
[3] Recorded only for patients who had intraperitoneal surgery.

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TABLE 147.—*Total reported incidence of clostridial myositis or cerebritis in 1,450 battle casualty deaths*

Clostridial infections	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Clostridial myositis of extremity:			
Evident	46	8	54
Suspected	----------	28	28
Clostridial myositis or cerebritis of head, neck, or trunk:			
Evident	5	4	9
Suspected	----------	10	10
Total	51	50	101

[1] Probably somewhat lower than the actual incidence.

TABLE 148.—*Total reported incidence of embolism, infarction, and thrombosis in 1,450 battle casualty deaths*

Pathological condition	Immediate cause of death	Contributory or associated condition	Total reported [1] incidence
Embolism, air:			
Evident	2	2	4
Suspected	----------	12	12
Embolism, fat:			
Evident	27	22	49
Suspected	----------	65	65
Embolism, thrombotic:			
Evident	20	14	34
Suspected	----------	17	17
Embolism, thrombotic, and infarction	----------	5	5
Infarction alone	3	13	16
Infarction and thrombosis	----------	9	9
Thrombosis alone:			
Evident	----------	35	35
Suspected	----------	3	3
Total	52	197	249

[1] Probably somewhat lower than the actual incidence.

TABLE 149.—*Total reported incidence of miscellaneous conditions in 1,450 battle casualty deaths*

Miscellaneous conditions	Immediate cause of death	Contributory or associated condition	Total reported[1] incidence
Anaphylaxis, suspected	----------	2	2
Anemia, refractory or severe	----------	13	13
Anesthetic agent:			
Cause of death	7	----------	7
Suspected	----------	25	25
Blast death, suspected	----------	29	29
Jaundice	----------	24	24
Malnutrition, severe	----------	10	10
Morphine poisoning:			
Cause of death	----------	----------	----------
Suspected	----------	4	4
Other contributory conditions	----------	2	2
Septicemia (excluding clostridial)	1	1	2
Transfusion reaction, severe	1	6	7
Respiratory failure, cause undetermined	1	----------	1
Undetermined, unclassified	303	----------	303
Total	313	116	429

[1] Probably somewhat lower than the actual incidence.

Detailed Observations[4]

In this section, the cases in each of the principal wound groups are considered separately, and in each of the subdivisions a tabulation lists the immediate cause of death for the cases in that particular group.

1. The immediate cause of death in the 297 cases in which the principal wound was intracranial is as follows:

	Number of cases
Neural trauma and/or intracranial hemorrhage or clot	210
Shock (all trauma and hemorrhage)	15
Pneumonia	12
Intracranial blast trauma alone	5
Clostridial myositis, extremity	3
Intracranial blast and other trauma	2
Thrombotic embolism (pulmonary)	2
Meningitis, intracranial	2
Pigment nephropathy	2
Brain abscess	1
Fat embolism (pulmonary)	1
Tracheobronchial obstruction, aspirated vomitus	1
Undetermined, intracranial condition	1
Undetermined, unclassified	40

[4] Additional detailed information on surgery, anesthesia, replacement therapy, chemotherapy, oxygen therapy, and other miscellaneous data are presented in appendix F, p. 813.

2. The immediate cause of death in the 27 cases in which the principal wound was intravertebral is as follows:

	Number of cases
Spinal cord trauma or hematomyelia	16
Shock (all trauma and hemorrhage)	4
Pneumonia	3
Tracheobronchial obstruction, aspirated vomitus	1
Undetermined, unclassified	3

3. The immediate cause of death in the eight cases in which the principal wound was maxillofacial is as follows:

	Number of cases
Tracheobronchial obstruction, blood and mucus	2
Fat embolism (pulmonary)	1
Shock (trauma and hemorrhage)	1
Undetermined, unclassified	4

4. The immediate cause of death in the 25 cases in which the principal wound was cervical is as follows:

	Number of cases
Shock	[1] 11
Cerebral ischemia	4
Thrombotic embolism (pulmonary)	2
Respiratory obstruction (above trachea)	2
Pigment nephropathy	1
Pneumonia	1
Tracheobronchial obstruction, blood and mucus	1
Undetermined, unclassified	3

[1] Includes 5 cases of cardiorespiratory embarrassment plus trauma and hemorrhage and 6 cases of trauma and hemorrhage.

5. The immediate cause of death in the 138 cases in which the principal wound was intrathoracic is as follows:

	Number of cases
Shock	[1] 70
Pneumonia	7
Empyema	5
Fat embolism (pulmonary)	4
Thrombotic embolism (pulmonary)	3
Cerebral ischemia	3
Pigment nephropathy	3
Coronary occlusion	2
Anesthetic agent	1
Pulmonary blast and other trauma	1
Pulmonary blast trauma alone	1
Clostridial myositis:	
Trunk	1
Extremity	1
Pulmonary infarction	1
Mediastinal hemorrhage	1
Myocardial decompensation, general	1
Tracheobronchial obstruction:	
Aspirated vomitus	1
Blood and mucus	1
Undetermined pulmonary complication	8
Undetermined, unclassified	23

[1] Includes 66 cases of cardiorespiratory embarrassment plus trauma and hemorrhage, 2 cases of contamination or sepsis plus trauma and hemorrhage, and 2 cases of trauma and hemorrhage.

6. The immediate cause of death in the 212 cases in which the principal wound was thoracoabdominal is as follows:

	Number of cases		Number of cases
Shock:		Clostridial myositis, trunk	2
Trauma and hemorrhage alone	2	Myocardial decompensation, general	2
Contamination or sepsis plus trauma and hemorrhage	1	Anesthetic agent	1
Contamination or sepsis plus cardiorespiratory embarrassment plus trauma and hemorrhage	59	Pulmonary blast and other trauma	1
Cardiorespiratory embarrassment plus trauma and hemorrhage	56	Fat embolism (pulmonary)	1
Pigment nephropathy	12	Empyema	1
Peritonitis	11	Pulmonary infarction	1
Pneumonia	3	Respiratory obstruction above trachea (maxillofacial wound)	1
Tracheobronchial obstruction, blood and mucus	3	Tracheobronchial obstruction, aspirated vomitus	1
Thrombotic embolism (pulmonary)	2	Ventricular arrest	1
		Thoracic trauma, unclassified	1
		Undetermined intracranial complication	1
		Undetermined thoracic complication	3
		Undetermined, unclassified	46

7. The immediate cause of death in the 59 cases in which the principal wound was combined intra-abdominal and intrathoracic is as follows:

	Number of cases		Number of cases
Shock:		Pigment nephropathy	6
Trauma and hemorrhage alone	4	Fat embolism (pulmonary)	2
Cardiorespiratory embarrassment and trauma and hemorrhage	7	Tracheobronchial obstruction, blood and mucus	2
Cardiorespiratory embarrassment and contamination or sepsis plus trauma and hemorrhage	10	Pulmonary blast trauma alone	1
Contamination or sepsis plus trauma and hemorrhage	4	Air embolism	1
Peritonitis	7	Clostridial myositis, trunk	1
		Neural trauma and/or hemorrhage or clot	1
		Pneumonitis	1
		Undetermined pulmonary condition	1
		Undetermined, unclassified	11

8. The immediate cause of death in the 408 cases in which the principal wound was intra-abdominal is as follows:

	Number of cases		Number of cases
Shock	179	Air embolism	1
Peritonitis	46	Blast trauma alone (pulmonary)	1
Pigment nephropathy	26	Myocardial decompensation (general)	1
Pneumonia	17	Sepsis, abdominal, unclassified	1
Clostridial myositis	9	Septicemia	1
Thrombotic embolism	8	Tracheobronchial obstruction, blood and mucus	1
Tracheobronchial obstruction, aspirated vomitus	5	Transfusion reaction	1
Fat embolism	4	Ventricular arrest	1
Cellulitis, extraperitoneal	3	Other condition (abdominal)	2
Abdominal abscess	2	Undetermined, abdominal cause	4
Anesthetic agent	2	Undetermined, unclassified	91
Intestinal obstruction	2		

9. The immediate cause of death in the three cases in which the principal wound was of the abdominal wall is as follows:

	Number of cases
Clostridial myositis, trunk	1
Undetermined, thoracic complication	1
Undetermined, unclassified	1

10. The immediate cause of death in the four cases in which the principal wound was upper extremity, soft tissue only, is as follows:

	Number of cases
Shock (trauma and hemorrhage)	1
Pigment nephropathy	1
Undetermined, unclassified	1

11. The immediate cause of death in the 10 cases in which the principal wound was upper extremity, bone and soft tissue, is as follows:

	Number of cases
Shock (trauma and hemorrhage)	3
Anesthetic agent	1
Clostridial myositis	1
Undetermined, unclassified	5

12. The immediate cause of death in the 31 cases in which the principal wound was lower extremity, soft tissue only, is as follows:

	Number of cases		Number of cases
Shock (all trauma and hemorrhage)	9	Anesthetic agent	1
Clostridial myositis, extremity	8	Fat embolism (pulmonary)	1
Pigment nephropathy	5	Meningitis, spinal	1
Pneumonia	2	Undetermined, unclassified	4

13. The immediate cause of death in the 114 cases in which the principal wound was unclassified multiple is as follows:

	Number of cases		Number of cases
Shock	46	Cerebral ischemia	1
Fat embolism (pulmonary)	4	Mediastinitis	1
Pigment nephropathy	4	Respiratory failure, cause undetermined	1
Clostridial myositis, extremity	3	Tracheobronchial obstructions:	
Intercranial, neural trauma and/or hemorrhage	2	Aspirated vomitus	1
Pneumonia	2	Blood and mucus	1
Abdominal cellulitis	1	Undetermined, unclassified	46
Thrombotic embolism (pulmonary)	4		

SPECIAL STUDIES ON INTRA-ABDOMINAL WOUNDS

In 408 cases (28.1 percent) of the 1,450 deaths studied, the principal wound was intra-abdominal. Adding the 212 cases having thoracoabdominal wounds and the 59 cases having combined intra-abdominal and intrathoracic wounds, a total of 679 (46.8 percent) deaths were due to wounds of the abdomen. The latter two groups are not included in the study in this section.

The group of 408 cases in which the principal wound was intra-abdominal have been studied as a group in the preceding sections of this chapter (p. 501). In this section, the 408 cases are considered in further detail.

Shock was the immediate cause of death in 43.6 percent of those 408 deaths in which the principal wound was intra-abdominal. An analysis of this group of shock deaths in abdominal wounds (178 cases) is presented in tables 150 through 153 and the tabulations which follow. It was found that 30.9 percent died before surgery in this group as compared to 7 percent in the remaining cases (table 154). Contamination from a perforated hollow viscus was a factor in 65 percent of those dying from shock (table 151) which was less than the incidence of 74 percent in the rest of the group. Hemoperitoneum or continuing hemorrhage was noted in 64 percent of the shock group and in 70 percent of the remainder. There was very little difference in the incidence of peritonitis in the two groups, the figure approximating 21 percent. Likewise, there was little difference in the incidence of associated wounds in the two groups (table 152).

In the study of the time interval between wounding to death in the cases with intra-abdominal wounds and dying of shock, it was found that 11 cases lived less than 1 hour and 35 cases died before induction of an anesthesia with an average survival time of 16 hours.

TABLE 150.—*Data relative to hospital admission, anesthesia, and surgery in 178 cases in which the principal wound was intra-abdominal and the immediate cause of death was shock*

Time of death	Total	
	Number	Percent
Dead on arrival	6	3. 4
Dying on admission	11	6. 2
Died before anesthesia [1]	35	19. 6
Died during anesthetic condition	3	1. 7
Died during primary surgery	16	9. 0
Died subsequent to primary surgery	107	60. 1
Total	178	100. 0

[1] Excludes the DOA and the dying on admission.

The following is a breakdown of the 178 cases in which the principal wound was intra-abdominal and the immediate cause of death was shock:

	Number of cases
Etiology of shock:	
Trauma and hemorrhage	57
Trauma and hemorrhage plus contamination or sepsis	114
Trauma and hemorrhage plus cardiorespiratory embarrassment	3
Trauma and hemorrhage plus contamination or sepsis plus cardiorespiratory embarrassment	2
Type or etiology undetermined	2

TABLE 151.—*Intra-abdominal pathology in 178 cases* [1] *in which the principal wound was intra-abdominal and the immediate cause of death was shock*

Intra-abdominal pathology	Incidence	
	Number	Percent
Contamination or sepsis a factor: [2]		
Peritonitis:		
Severe	20	10.81
Mild or moderate	17	9.20
Suspected	6	3.24
Primary abdominal hemorrhage	[3] 89	48.11
Recurrent or delayed abdominal hemorrhage	5	2.70
Hemorrhage, profuse in hospital	12	6.49
Total	149	80.55
Contamination or sepsis not a factor:		
Peritonitis:		
Severe	----------	----------
Mild or moderate	1	.54
Suspected	----------	----------
Primary abdominal hemorrhage	[3] 25	13.51
Recurrent or delayed abdominal hemorrhage	4	2.16
Hemorrhage, profuse in hospital	6	3.24
Total	36	19.45
Grand total	185	100.00

[1] Contamination or sepsis was a factor in 116 cases and not a factor in the remaining 62 cases.
[2] Contamination from hollow viscus.
[3] Includes those cases in which note was made of hemoperitoneum or of active intra-abdominal bleeding.

In the 178 cases in which the principal wound was intra-abdominal and the immediate cause of death was shock, there was an incidence of 193 associated and, in many instances, multiple wounds, as follows:

	Number of wounds
Intracranial:	
Known	1
Suspected	5
Scalp	4
Maxillofacial:	
Bone and soft tissue	3
Soft tissue only	8
Cervical, general	3
Intraspinal	13
Chest wall	17
Pulmonary blast injury	1
Intrathoracic, suspected	7
Upper extremity:	
Bone and soft tissue	9
Soft tissue only	37
Traumatic amputation	1
Lower extremity:	
Bone and soft tissue	14
Soft tissue only	68
Traumatic amputation	3
Total	193

There were no associated wounds in 60 of these 178 cases.

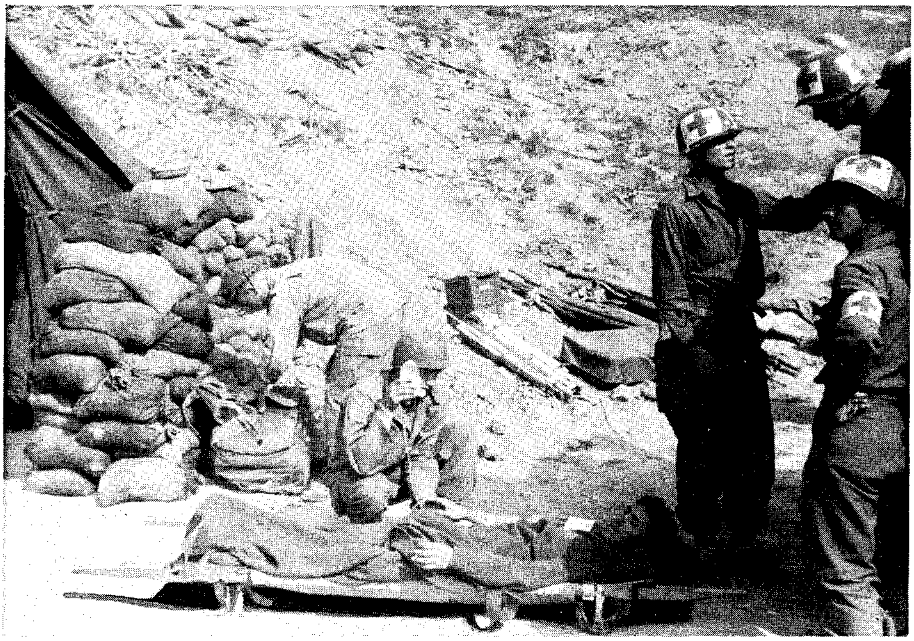

FIGURE 263.—Plasma being administered to a casualty at a battalion aid station.

The records of plasma and blood administered can be very difficult to interpret. In a surprisingly large percentage of cases, there was no record of any blood transfusion. It is possible that some received blood and no record was made, but also probable that in the majority no blood was administered. The averages given (table 152) are based only on those cases in which blood was given and a record made of its administration. The data on the amount of plasma administered before admission represent the replacement therapy carried out in battalion aid stations (fig. 263), collecting stations, and clearing stations. While it is believed that only the minimum amount of plasma necessary to insure transportability of the patient should be given, just what that amount is in each case has to be determined by the individual medical officer in charge. That his judgment had been excellent in nearly every case is a statement to which medical officers in Army hospitals will attest. Comparing the averages and the number receiving blood in the group dying in shock with the whole group of cases, it was found that a larger percentage of cases received a larger average amount of blood in the shock group than in the group as a whole. Inasmuch as this series involved only deaths and there were no figures at hand for the cases with intra-abdominal wounds who lived, comparisons could not be made with a group of cases in which therapy was adequate.[5]

[5] It is our opinion that in the group of cases who died the amount of blood administered was inadequate.—H. E. S. and J. W. C.

TABLE 152.—*Transfusion record in group of 178 cases in which the principal wound was intra-abdominal and the immediate cause of death was shock*

Time of transfusion	Number receiving transfusion of—		Average number of units administered	
	Plasma	Blood	Plasma (250 cc. units)	Blood (500 cc. units)
Before admission	130	------	3.18	------
After admission, before surgery	77	112	3.16	3.03
During surgery	23	55	2.95	3 19
After surgery	16	27	2.25	3 07

The percent of bullet wounds in the shock deaths in the intra-abdominal group was 17.4 percent (table 153) as compared with 19.6 percent in the entire intra-abdominal group, while in the whole series (1,450) it was only 15.0 percent.

TABLE 153.—*Distribution of group of 178 cases in which the principal wound*[1] *was intra-abdominal and the immediate cause of death was shock, by causative agent*

Causative agent	Number of cases	Percent of cases
Bullet:		
Unclassified	23	12.9
Rifle	2	1.1
Machinegun	6	3.4
High explosive:		
Unclassified	17	9.5
Shell	116	65.2
Mine	3	1.7
Boobytrap	------	------
Bomb	8	4.5
Blast	------	------
No record	3	1.7
Total	178	100.0

[1] The type of wound in this group was penetrating in 125 cases and perforating in 53 cases.

The following tabulation lists the miscellaneous conditions occurring in the group of 178 cases with intra-abdominal wounds who died of shock:

	Number of cases
Myocardial decompensation:	
Evident	2
Suspected	14
Pulmonary edema:	
Severe	1
Slight or moderate	12
Tracheobronchial obstruction:	
Aspirated vomitus	----
Tracheobronchial obstruction—Con.	
Blood and mucus	3
Suspected	1
Thoracic trauma (chest wall)	18
Pigment nephropathy:	
Evident	1
Suspected	5
Renal trauma, evident	24

Myocardial decompensation was evident in only two cases, and, in these, excessive administration of plasma and blood was thought responsible. Pulmonary edema was noted in 13 cases in the group. As this is an unusual occurrence in uncomplicated shock, a search was made for factors predisposing to pulmonary edema. All 13 cases received plasma and blood before surgery. The average units received were little different from the averages for those receiving plasma and blood in the rest of the group in which, however, a substantial number received none. It was difficult to draw any conclusions regarding the role plasma and blood played in the appearance of pulmonary edema in this group. Thoracic trauma, blast trauma, and pneumonia probably contributed to the incidence of "pulmonary edema."

Study of blood pressure records revealed that 17 of the 55 recorded admission blood pressures were zero. The lowest pressure recorded was zero in 34 of the 70 cases where records were available. The average duration of surgery in this shock group approached 2½ hours. All cases coming to surgery received ether anesthesia. Thiopental sodium (Pentothal sodium) was used once and nitrous oxide 40 times for induction.

Table 154 and the tabulations which are to follow deal with those cases (230) in which the principal wound was intra-abdominal but the immediate cause of death was not shock. It should be noted that there was no evidence of shock in only six of these cases. The remainder had evidence of shock at some time during the course of their hospital stay.[6] Analysis of shock as a contributory or associated condition is included in the study of this group of cases.

The incidence of shock as a contributory or associated condition in the group of 230 cases in which the principal wound was intra-abdominal and the immediate cause of death was not shock follows:

Contributory or associated condition of shock:	*Number of cases*
Corrected by therapy	121
Suspected, not proved	16
Present, successful correction doubtful	66
Uncorrected	21
No evidence	6

[6] The terminal fall in blood pressure occurring in every case immediately before death was not regarded as evidence of shock.

Table 154.—*Data relative to hospital admission, anesthesia, and surgery, in 230 cases in which the principal wound was intra-abdominal and the immediate cause of death was not shock*

Time of death	Number of cases	Percent of cases
Dead on arrival	----------	----------
Dying on admission	1	0. 4
Died before anesthesia [1]	10	4. 4
Died during anesthetic induction	5	2. 2
Died during primary surgery	4	1. 7
Died subsequent to primary surgery	210	91. 3
Total	230	100. 0

[1] Excludes the DOA and those dying on admission.

Miscellaneous findings in 230 cases in which the principal wound was intra-abdominal but the immediate cause of death was not shock but with shock as a contributory or associated condition (224 cases) were as follows:

	Number of cases
Hemorrhage:	
Profuse in hospital	11
Primary	156
Recurrent or delayed	10
Peritoneal contamination from hollow viscus	165
Peritonitis:	
Severe	17
Mild or moderate	31
Suspected	40

In the 230 cases in which the principal wound was intra-abdominal but the immediate cause of death was not shock, the incidence of associated wounds was as follows:

Associated wounds:	*Number of cases*
Intracranial:	
Known	1
Suspected	1
Scalp	3
Maxillofacial, bone and soft tissue	1
Eye or orbit	2
Maxillofacial and soft tissue only	7
Neck, general	6
Intraspinal, unclassified	13
Chest wall only	22

Associated wounds—Continued	*Number of cases*
Pulmonary blast	4
Intrathoracic, suspected	10
Thoracoabdominal	1
Upper extremity:	
Soft tissue only	28
Traumatic amputation	1
Lower extremity:	
Soft tissue only	72
Bone and soft tissue	46
Traumatic amputation	2

There were no associated wounds in 70 of the 230 cases.

A further breakdown of the group of 408 cases in which the principal wound was intra-abdominal is presented in tables 155 through 159. The data presented in those tables are for a group of 175 cases in which peritonitis was

evident or suspected to be present. It was believed that a better picture of intra-abdominal wounds might be obtained if they were not complicated by factors originating from concomitant wounds of the chest and diaphragm. Those with peritonitis and suspected peritonitis were examined in three groups (table 155). The first group was composed of those in which peritonitis was the immediate cause of death. In the second group, peritonitis was evident but not the immediate cause of death. This included the cases listed under contributory or associated conditions as "peritonitis, severe" and "peritonitis, mild or moderate." The third group was made up of those cases in which peritonitis was suspected but the evidence was not sufficient to confirm its presence.

TABLE 155.—*Data relative to hospital admission, anesthesia, and surgery, in 175 cases in which the principal wound was intra-abdominal and peritonitis was evident or suspected to be present*

Time of death	Peritonitis immediate cause of death	Peritonitis contributory to death	Peritonitis suspected
Before anesthesia	----------	2	----------
During anesthetic induction	----------	2	----------
During primary surgery	----------	3	----------
After primary surgery	46	76	46
Total	46	83	46

TABLE 156.—*Operating time for primary surgery in 175 cases in which the principal wound was intra-abdominal and peritonitis was evident or suspected to be present*

Operating time (minutes)	Peritonitis immediate cause of death	Peritonitis contributory to death	Peritonitis suspected
Less than 30	----------	2	----------
30 to 59	----------	1	----------
60 to 89	1	----------	1
90 to 119	1	3	1
120 to 149	----------	5	3
150 to 179	3	4	----------
180 to 209	4	6	----------
210 to 239	2	1	----------
240 to 299	1	1	----------
300 to 360	----------	1	----------
Not stated	34	59	41
Total	46	83	46
Average time	180	154	117

TABLE 157.—*Data relative to primary surgery on 175 cases in which the principal wound was intra-abdominal and peritonitis was evident or suspected to be present*

Type of surgery	Peritonitis immediate cause of death		Peritonitis contributory to death		Peritonitis suspected		Total	
	Number	Percent of operations	Number	Percent of operations	Number	Percent of operations	Number	Percent of operations
Laparotomy	45	49. 4	80	49. 1	44	48. 9	169	49. 1
Debridement, abdominal wall wound only	------	------	2	1. 2	1	1. 1	3	. 9
Debridement, other wounds:								
Associated with primary operation	41	45. 1	44	27. 0	26	28. 9	111	32. 3
Omitted deliberately	1	1. 1	4	2. 5	1	1. 1	6	1. 7
Partially done	1	1. 1	8	4. 9	------	------	9	2. 6
Not stated	3	3. 3	25	15. 3	18	20. 0	46	13. 4
Total	91	100. 0	163	100. 0	90	100. 0	344	100. 0

TABLE 158.—*The immediate cause of death in 175 cases in which the principal wound was intra-abdominal and peritonitis was evident or suspected to be present*

Immediate cause of death	Peritonitis immediate cause of death	Peritonitis contributory	Peritonitis suspected
Peritonitis	46	----------	----------
Shock	----------	39	6
Pigment nephropathy	----------	12	----------
Pneumonia	----------	9	2
Fat embolism (pulmonary)	----------	3	----------
Thrombotic embolism (pulmonary)	----------	2	----------
Cellulitis, abdominal	----------	1	1
Clostridial myositis:			
Trunk	----------	1	----------
Extremity	----------	1	1
Intestinal obstruction	----------	1	----------
Sepsis, abdominal, unclassified	----------	1	----------
Tracheobronchial obstruction, aspirated vomitus	----------	1	----------
Transfusion reaction	----------	----------	1
Undetermined:			
Abdominal	----------	2	----------
Unclassified	----------	14	35
Total	46	87	46

TABLE 159.—*Etiology of shock as a contributory or associated condition in 175 cases in which the principal wound was intra-abdominal and peritonitis was evident or suspected to be present*

Etiology or type of shock	Peritonitis immediate cause of death	Peritonitis contributory	Peritonitis suspected
Cardiorespiratory embarrassment plus trauma and hemorrhage	1	----------	1
Cardiorespiratory embarrassment plus trauma and hemorrhage plus contamination or sepsis	----------	1	----------
Contamination of sepsis plus trauma and hemorrhage	42	41	35
Trauma and hemorrhage	1	6	4

CASES IN WHICH THE IMMEDIATE CAUSE OF DEATH WAS SHOCK

The 523 cases which have been listed under this heading were those in which there was good evidence of peripheral circulatory failure initiated by the initial trauma and hemorrhage and perpetuated by trauma and hemorrhage with or without the added shock-producing factors of cardiorespiratory embarrassment, peritoneal contamination from a wound of a hollow viscus or early sepsis, or any combination of these factors. The data on the "Etiology of shock" reveal the evidence of these various factors. No effort was made to separate the factors of trauma and hemorrhage, as both occurred in varying degrees and proportions in every battle casualty. In 13 cases, recurrent or delayed abdominal hemorrhage was a factor. In the 245 cases who died of shock after primary surgery, only 43 lived more than 24 hours after the surgery.

Tables 160 through 165 which follow relate to the 523 cases in the series of 1,450 deaths in which shock was listed as the immediate cause of death. In addition, there were 750 other cases in which shock was a contributory or associated condition. There was no evidence of shock in only 177 of the 1,450 deaths studied. It is not within the province of this report to discuss in detail the etiology of shock. However, it should be stated that clinical experience and laboratory investigations demonstrated that loss of whole blood was the most important factor in the vast majority of battle casualties in shock. The amount of blood lost was far in excess of previous estimates. In 1945, whole blood was given to 40.6 percent of the battle casualties admitted to Fifth U.S. Army hospitals at a rate of 2.52 pints per casualty transfused.[7] Many casualties were given as much as 6 or 8 pints of blood and a few even more in the first 24 hours after their admission to the hospital. Plasma loss per se was found only in burns, crush injuries, gas gangrene, sepsis, and gross

[7] Data based on reports of hospitals to the Fifth U.S. Army surgeon.

contamination of the peritoneal or pleural cavities.[8] In the latter two categories, plasma loss was often less than whole blood loss. Inasmuch as blood was not available except in exceptional circumstances at battalion aid and collecting and clearing stations, some of the most severely wounded casualties, or those in the most severe grade of shock from their wounds, were often given large quantities of plasma to render them transportable to the hospital. These casualties were frequently again in severe shock by the time they arrived at the hospital, and further resuscitation was complicated because the remaining blood in their vascular tree was well diluted with plasma.

Among contributing factors in shock deaths were the following:

1. The use of large quantities of plasma to combat lowered blood volume when the loss has been of whole blood.
2. Unrecognized and/or uncontrolled continued bleeding.
3. Inadequate or poorly timed blood replacement with whole blood.
4. Delayed surgery in those cases in which there has been gross contamination of peritoneal and pleural cavities with contents of the gastrointestinal tract, or in which sepsis is developing.

TABLE 160.—*Location of principal wound in 523 cases in which the immediate cause of death was shock*

Location of principal wound	Number of cases	Percent of cases
Intra-abdominal	178	34. 03
Thoracoabdominal	118	22. 56
Intrathoracic	70	13. 39
Unclassified, multiple	46	8. 80
Lower extremity, bone and soft tissue	41	7. 84
Combined intra-abdominal and intrathoracic	25	4. 78
Intracranial	15	2. 87
Cervical	11	2. 10
Lower extremity, soft tissue	9	1. 72
Intravertebral	4	. 77
Upper extremity:		
Bone and soft tissue	3	. 57
Soft tissue	2	. 38
Maxillofacial	1	. 19
Abdominal wall	-----------	-----------
Total	523	100. 0

[8] (1) Stewart, J. D., and Warner, F. F.: Observations on the Wounded in Forward Field Hospitals With Special Reference to Wound Shock. Ann. Surg. 122: 129, 1945. (2) Simeone, F. A.: Personal communication to the authors based on work of the Board for the Study of the Severely Wounded.

5. Failure to recognize and/or control factors leading to cardiorespiratory embarrassment. Included in this group are hemothorax, pneumothorax, cardiac tamponade, tracheobronchial obstruction from blood or mucus, painful chest wall wounds, and gastric dilatation.

6. Failure to control pain by morphine, procaine hydrochloride (Novocain) nerve block, proper splinting of painful extremity wounds, and timely surgery.

TABLE 161.—*Data relative to hospital admission, anesthesia, and surgery in 523 cases in which the immediate cause of death was shock*

Time of death	Number of cases	Percent of cases
Dead on arrival	25	4. 8
Dying on admission	55	10. 5
Died before anesthesia [1]	135	25. 8
Died during anesthetic induction	6	1. 1
Died during primary surgery	48	9. 2
Died subsequent to primary surgery	254	48. 6
Total	523	100. 0

[1] Excludes the DOA and those dying on admission.

TABLE 162.—*Etiology of shock in 523 cases in which shock was the immediate cause of death*

Etiology of shock	Number of cases in group—						Total number of cases
	I	II	III	IV	V	VI	
Trauma and hemorrhage	15	35	71	----	10	53	184
Contamination or sepsis plus trauma and hemorrhage	1	2	10	3	11	93	120
Cardiorespiratory embarrassment plus trauma and hemorrhage plus contamination or sepsis	1	1	10	----	12	48	72
Cardiorespiratory embarrassment plus trauma and hemorrhage	8	17	44	3	15	60	147
Total	25	55	135	6	48	254	523

NOTE.—Key for roman numerals:
- I Dead on arrival.
- II Dying on admission.
- III Died before anesthesia (excludes I and II).
- IV Died during anesthetic induction.
- V Died during primary surgery.
- VI Died subsequent to primary surgery.

TABLE 163.—*Lowest recorded blood pressure [1] and other evidence in 498 cases in which the immediate cause of death was shock*

Blood pressure record and evidence of shock	Number of cases in group—					Total number of cases
	II	III	IV	V	VI	
Shock present:						
0	10	26	1	7	47	91
2 to 38	----	----	1	1	2	4
40 to 58	----	10	----	2	16	28
60 to 78	1	9	1	3	28	42
80 to 88	2	7	----	2	18	29
90 to 98	----	3	----	2	8	13
100 or more, but pulse rapid and weak [2]	----	----	----	1	3	4
Presence of shock recorded	18	52	2	15	77	164
Shock suspected by inference	9	7	----	2	4	22
Treatment suggests shock	15	21	1	13	51	101

[1] Excluding the gradual terminal decline immediately preceding death.
[2] No comment on shock in record.

NOTE.—Key for roman numerals:
II Dying on admission.
III Died before anesthesia (excludes II).
IV Died during anesthetic induction.
V Died during primary surgery.
VI Died subsequent to primary surgery.

TABLE 164.—*Primary operations performed on 327 cases in which the immediate cause of death was shock*

Type of operation	Died during primary surgery	Died following primary surgery	Total number of cases
Abdominal stab incision	1	6	7
Amputation	2	17	19
Craniotomy	1	4	5
Debridement only	5	36	41
Laminectomy	1	3	4
Laparotomy	5	168	173
Other operation	1	3	4
Thoracolaparotomy	3	7	10
Thoracotomy	14	50	64

TABLE 165.—*Miscellaneous observations in 219 cases in which the immediate cause of death was shock*

Miscellaneous observations	Number of cases in group—					Total number of cases
	II	III	IV	V	VI	
Burns present	2	3	----	----	4	9
Coma on admission	8	20	----	1	7	36
Cyanosis, marked	----	2	----	3	4	9
Dying on admission	55	----	----	----	----	55
Exposure, severe, before admission	----	----	----	----	2	2
Hemorrhage, profuse, in hospital	----	1	----	9	19	29
Pallor noted	4	2	----	1	2	9
Peritoneal closure impossible	----	----	----	----	4	4
Sweating noted	1	2	----	----	2	5
Tourniquet used before admission	6	10	----	1	12	29
Two or more of these present	18	6	----	1	7	32

NOTE.—Key for roman numerals:
II Dying on admission.
III Died before anesthesia (excludes II).
IV Died during anesthetic induction.
V Died during primary surgery.
VI Died subsequent to primary surgery.

PIGMENT NEPHROPATHY IN BATTLE CASUALTIES

The development of progressive oliguria and anuria in battle casualties resuscitated from shock and apparently on the road to recovery following extensive surgical procedures led to the death of a significant number of severely wounded soldiers. Death usually occurred between the fourth and eighth days after the wound was incurred. At autopsy, the kidneys were observed to be somewhat enlarged, and on microscopic examination pigment casts were seen in the distal convoluted and collecting tubules. The proximal tubules were dilated, and a varying degree of necrosis of the distal tubules was observed, with some inflammatory reaction in the adjacent stroma. The capillary tufts in the glomeruli showed no changes, but there was in some cases slight swelling of the cells in Bowman's capsule. This lesion has been variously termed pigment nephropathy, hemoglobinuric nephrosis, and lower nephron nephrosis.

Among the 1,411 deaths, lower nephron nephrosis or pigment nephropathy led to death in 68 cases (table 166) and contributed to death in 31 others. It was suspected to have been present in 57 additional cases. Autopsy was performed in all but 9 of the 99 cases in which pigment nephropathy was known to be present, and microscopic study of renal sections was reported in 67 of the 90 cases in which autopsy was performed.

TABLE 166.—*Distribution of 1,411 hospital battle casualty deaths, by result or status of pigment nephropathy*

Result or status of pigment nephropathy	Number of cases	Percent of cases
Led to death	68	4.8
Contributed to death	31	2.2
Suspected	57	4
Total	156	11

A study of the 99 cases in which pigment nephropathy was known to be present forms the basis of this presentation. Of significance are the severity and multiplicity of wounds encountered in this group. The following tabulations list the site of the principal wounds and of the associated wounds in this group of 99 cases of pigment nephropathy:

Site of principal wounds:	*Number of cases*
Intra-abdominal area	45
Combined intra-abdominal and intrathoracic area	6
Thoracoabdominal area	8
Intrathoracic area	4
Intracranial area	8
Intraspinal area	2
Lower extremity	18
Upper extremity	1
Cervical area	2
Unclassified, multiple areas	5
Total	99

Site of associated wounds:	*Number of wounds*
Intracranial area	5
Maxillofacial area (bones and soft tissue)	3
Eye or orbit	3
Maxillofacial area (soft tissue only)	9
Neck	9
Intraspinal area	7
Thoracic wall	6
Intrathoracic area	10
Suspected intrathoracic area	2
Abdominal wall (exclusive of intra-abdominal cases)	7
Combined intra-abdominal and intrathoracic area	1
Intra-abdominal area	1
Suspected intra-abdominal area	3
Upper extremity (includes 2 traumatic amputations)	44
Lower extremity (includes 2 traumatic amputations)	49
Total	149

It will be noted that the abdominal cavity was involved in 59 cases and that intra-abdominal wounds were present as associated wounds in 2 more cases and suspected in 3 others. In only 20 cases were no wounds present other than the one or ones listed as principal wounds. The 149 associated wounds occurred in 79 cases, for a total of 238 wounds.[9]

[9] Multiple wounds confined to one region of the body, such as the lower extremity or the intra-abdominal area, were listed as only one wound. The same is true of the 20 cases in which no associated wounds are listed, as in many of these cases there were multiple shell fragment or bullet wounds confined to one region of the body.

In all the deaths in battle casualties studied, attempt was made to ascertain an immediate cause of death. Lower nephron nephrosis was regarded as the immediate cause of death in 68 cases. In 31 cases, some other cause was thought to be the immediate cause of death, as is shown in the following tabulation:

Immediate cause of death:	*Number of cases*
Fat embolism	3
Thrombotic pulmonary embolism	3
Clostridial myositis (gas gangrene)	4
Intracranial hemorrhage, trauma	3
Peritonitis	1
Pneumonia	2
Shock	5
Spinal cord trauma	1
Undetermined intra-abdominal lesion	2
Unclassified, undetermined	7

The so-called immediate cause of death, however, fails to give a complete picture of the multiplicity of pathologic conditions existing in this group of 99 cases. The contributory or associated conditions existing in this group are shown in the tabulation which follows.

Contributory or associated condition:[1]	*Number of cases*
Intracranial abscess	1
Intracranial blast trauma	1
Encephalomalacia	6
Intracranial hemorrhage or hematoma	7
Cerebral ischemia	2
Meningitis	1
Cerebral trauma, unclassified	6
Maxillofacial trauma	14
Total intracranial	38
Cervical hemorrhage	3
Cervical trauma	8
Total cervical	11
Hematomyelia	4
Spinal cord hemorrhage	1
Transection of spinal cord	2
Partial transection of spinal cord	1
Spinal cord trauma	8
Total intraspinal	16
Crushing trauma of extremity	3
Frostbite or immersion syndrome	1
Extremity hemorrhage	15
Sepsis in extremity	8
Extremity trauma	66
Total extremities	93
Abdominopelvic trauma	14
Extraperitoneal abscess	2
Intraperitoneal abscess	6
Adrenal hemorrhage	3
Adynamia ileus, severe	5
Adynamia ileus, mild or moderate	7
Abdominal blast trauma	2
Abdominal blast trauma, suspected	3
Cellulitis, mural and extraperitoneal	3
Peritoneal contamination from hollow viscera	39
Crushing trauma of abdomen	1
Crushing trauma of abdomen, suspected	1
Evisceration, postoperative	1
Gangrene of bowel	1
Gastric dilatation	6
Abdominal hemorrhage, primary	50
Abdominal hemorrhage, recurrent or delayed	2

See footnote on page 518.

Contributory or associated condition[1]—Continued	Number of cases
Hepatic degeneration, toxic	16
Hepatitis, epidemic	4
Hepatitis, epidemic, suspected	1
Inflammation of gastrointestinal tract	2
Intestinal obstruction, severe	1
Intestinal obstruction, mild or moderate	1
Leaking suture line	1
Nephropathy evident, unclassified	31
Operative wound infection	3
Pancreatic hemorrhage	1
Pancreatic trauma	1
Peritonitis, severe	7
Peritonitis, mild or moderate	18
Peritonitis, suspected	2
Renal repair, parenchymal	2
Renal trauma	18
Renal trauma, suspected	2
Splenic degeneration, toxic	4
Splenomegaly	6
Unrepaired wound of hollow viscus	1
Ureter traumatized or tied	3
Urinary tract repairs	1
Total abdominal	262
Pulmonary atelectasis, severe	1
Pulmonary atelectasis, mild or moderate	13
Pulmonary blast trauma	9
Pulmonary blast trauma, suspected	6
Bronchial fistula	1
Cardiac trauma	1
Cardiac trauma, suspected	1
Continuing intrapleural hemorrhage	1
Crushing trauma of chest	1
Dilatation of heart, severe	9
Dilatation of heart, slight or moderate	11
Empyema, mild or moderate	1
Empyema, suspected	1
Hemopneumothorax	27
Hemothorax without pneumothorax	3
Hydrothorax, severe	1
Hydrothorax, slight or moderate	23
Intrapulmonary hemorrhage, severe	7
Intrapulmonary hemorrhage, mild or moderate	21
Mediastinal edema	3
Mediastinal hemorrhage	3
Myocardial decompensation	27
Myocardial decompensation, suspected	27
Pneumonia, severe	4
Pneumonia, mild or moderate	19
Pneumonia, suspected	3
Pneumonitis	3
Pulmonary edema, severe	45
Pulmonary edema, slight, moderate	12
Purulent bronchitis	3
Tension pneumothorax	3
Tracheobronchial obstruction with blood and mucus	1
Thoracic trauma	13
Pleural contamination from hollow viscera in abdomen	1
Total thoracic	305
Gas gangrene of extremity	2
Gas gangrene of extremity, suspected	3
Gas gangrene of head, neck or trunk	1
Pulmonary fat embolism	8
Pulmonary fat embolism, suspected	4
Thrombosis, renal artery	3
Pulmonary thrombotic embolism	5
Pulmonary thrombotic embolism, suspected	1
Infarction of kidney	1
Infarction of lung	1
Thrombosis, intracranial vessel	1
Thrombosis, extremity artery	2
Thrombosis, extremity veins	1
Anemia, refractory or severe	8
Jaundice	10
Malnutrition, severe	1
Transfusion reaction, severe	3
Total general	57

[1] These are in addition to the condition listed as the immediate cause of death.

Pulmonary complications were so frequent as to be almost the rule. In many cases, the giving of intravenous fluids in the absence of urinary excretion led to high volume of the blood, cardiac failure, and pulmonary edema. Toxic hepatic degeneration was present in 16 cases, epidemic hepatitis in 4 cases (suspected in 1 more), and septic hepatitis secondary to trauma in 2 cases (suspected in 3 more). There was recorded evidence of renal trauma in 18 of the 99 cases, and a ureter had been traumatized or tied in 3 other cases. Fat embolism was the immediate cause of death in 3 cases, contributing cause of death in 8 cases, and was suspected as contributory to death in 4 more cases. The 11 cases in 99 represent an incidence of 11 percent, which is considerably higher than in the whole series of 1,411 battle casualty deaths, in which 49 cases constitute only 3.5 percent. It is also interesting to note that, in the 49 patients known to have pulmonary fat embolism, 11 had pigment nephropathy. Severe reactions from blood transfusion were noted in only 3 of the 99 cases. Gross infection was evident in 61 cases.

One outstanding feature in the cases in which anuria developed was the severity of the shock which occurred sometime between wounding and the development of renal insufficiency. In the 99 cases in which pigment nephropathy was known to exist, the lowest recorded blood pressures, along with other data relative to shock, are as follows:

Systolic blood pressure recording:	*Number of cases*
0	22
2–38	1
40–58	9
60–78	13
80–88	6
90–98	5
Presence of shock stated (no other data)	13
Treatment suggests shock (no other data)	25
No evidence of shock	5
Total	99

The five cases, the records of which gave no evidence of shock, are of sufficient interest to warrant presentation of case summaries (cases 3, 4, 5, 6, and 7).

It must be remembered that many of the records were rather incomplete. Data regarding the duration of low blood pressure were available in only a few instances. No data concerning the level of blood pressure before admission to a hospital are available. The amount of plasma administered before admission is perhaps the best index of shock at that time. The number of

units of 250 cc. of plasma administered in 99 cases of pigment nephropathy before admission to a hospital installation was as follows:

Units of plasma:	Number of cases
None or no record	25
1	16
2	19
3	22
4	10
5	3
6	1
8	1
10	1
11	1

There was evidence of shock in 94 of the 99 cases of pigment nephropathy. Trauma and hemorrhage were the leading causative factors in the development of shock. Additional contributory factors were cardiorespiratory embarrassment and contamination of the peritoneum or of an extremity. The amounts of plasma and blood used after admission to the hospital are further indexes of the degree of shock in these patients. The recorded data available concerning the administration of plasma and of blood are shown in the following tabulation:

Units of plasma administered—	Number of cases
Before admission:	
No record	25
1	16
2	19
3	22
4	10
5	3
6	1
7	---
8	1
9	---
10	1
11	1
After admission, before operation:	
No record	60
1	12
2	16
3	4
4	2
5	2
6	2
7	---
8	---
9	---
10	---
11	1
During operation:	
No record	75
1	9
2	8
3	2
4	2
5	1
6	2
7	---
8	---
9	---
10	---
11	---
After operation:	
No record	68
1	7
2	7
3	5
4	5
5	---
6	4
7	2
8	1
9	---
10	---
11	---

Pints of blood administered—	Number of cases
Before operation:	
No record	33
1	10
2	10
3	13
4	14
5	11
6	3
7	2
8	1
9	2
10	---
11	---

Pints of blood administered—Con. During operation:	Number of cases	Pints of blood administered—Con. After operation:	Number of cases
No record	45	No record	49
1	14	1	23
2	14	2	8
3	6	3	5
4	6	4	8
5	2	5	4
6	5	6	1
7	2	7	1
8	2	8	---
9	2	9	---
10	---	10	---
11	1	11	---

Treatment with oxygen might be expected in a larger percentage of patients than is shown in the following tabulation:

Oxygen therapy:	Number of cases	Oxygen therapy—Continued	Number of cases
No record	36	During operation	47
Before operation	13	After operation	27

The operating time for primary surgical treatment, shown in the tabulation which follows, is a further index of the severity of the wounds in this group of cases.

Operating time (minutes):	Number of cases	Operating time (minutes)—Con.	Number of cases
Less than 30	--	180–209	7
30–59	--	210–239	2
60–89	1	240–299	4
90–119	3	300–359	2
120–149	2	More than 360	2
150–179	3		

Unfortunately, the time was not stated in 62 of the cases; no operation was performed in 11 cases. In the remaining 26 cases, however, it was seen that in only one case did the operation last less than 1½ hours, while in the largest group of cases the operating time was from 3 to 3½ hours.

Data concerning anesthesia in the 68 patients who died of pigment nephropathy are presented in table 167. It will be noted that, with the exception of four patients who died before anesthesia was complete, all of whom had crush injuries, all had been given ether. In table 168, the anesthesia in 31 cases in which pigment nephropathy was a contributing cause of death is recorded. Of this group, seven patients died before anesthesia was complete; one had local anesthesia only; and all of the rest had ether anesthesia in one form or another. The patient who had local anesthesia only had an intracranial wound and died of pneumonia, septic hepatitis, and jaundice. There was a record of adequate urinary output and no evidence of shock. On the basis of microscopic autopsy alone, the diagnosis of pigment nephropathy was made. Data for seven patients who died before the induction of anesthesia

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in this group are presented in table 169. The diagnosis of pigment nephropathy in each of these cases is based on microscopic study of renal sections. All the patients had severe wounds; most of them died after a comparatively short time of being wounded, and correction of shock was doubtful or shock was completely uncorrected in all but one patient. Data concerning the amount of urine passed were unavailable. Since ether was considered to be the anesthetic of choice in all battle casualties with shock or severe wounds, no significance can be attached to the high incidence of ether anesthesia in this group of patients with pigment nephropathy.

TABLE 167.—*Anesthesia in 68 patients who died of pigment nephropathy*

Type of anesthesia	Number of patients at—	
	Primary operation	Secondary operation
Ether:		
Closed system	31	2
Open drop	3	0
Unclassified	15	2
Endotracheal [1]	28	1
Nitrous oxide [1]	28	2
Thiopental sodium [1]	3	2
No record	14	3
Death occurred before induction of anesthesia [2]	4	3

[1] All were known to have had ether, alone or in combination with another agent.
[2] All had crush injuries.

TABLE 168.—*Anesthesia in 31 patients in which pigment nephropathy contributed to death*

Type of anesthesia	Number of patients at—	
	Primary operation	Secondary operation
Ether:		
Closed system	13	1
Flagg method	1	4
Open drop	1	0
Unclassified	5	0
Endotracheal	7	0
Nitrous oxide	11	1
Local [1]	1	1
Thiopental sodium	0	0
No record	3	2
Death occurred before anesthesia was complete	7	0

[1] Specific agent not known.

TABLE 169.—*Analysis of 7 cases in which death occurred before anesthesia and in which pigment nephropathy contributed to death* [1]

Wounds	Immediate cause of death	Shock	Timelag from wounding to death (hours)	Urinary output
Intracranial and the abdominal wall.	Pulmonary embolism (thrombotic).	Uncorrected; lowest blood pressure recorded 60/20.	Not recorded.	Record inadequate.
Intraspinal, neck, intrathoracic (bilateral), and upper extremity.	Undetermined	Corrected; administered blood; pressure 50/0.	14	No record.
Intracranial (bilateral) and multiple.	Shock	Uncorrected	33	Do.
Intraspinal, intracranial, maxillofacial, neck, and upper extremity.	Spinal cord trauma.	Shock; correction doubtful.	113	Do.
Traumatic amputation and lower extremity.	Fat embolism	do	25	Do.
Multiple, extremities, and face.	Gas gangrene	Uncorrected	76	Record inadequate.
Intracranial, both lower extremities, and one upper extremity.	do	do	73	

[1] Diagnosis of pigment nephropathy in each instance was based on microscopic study of renal sections.

When the first cases of anuria were encountered, the sulfonamide drugs were regarded as the probable causative factor. Sulfanilamide powder was dusted into almost every wound on the battlefield, and most of the wounded soldiers had taken 4 gm. by mouth before reaching the hospital. Early in the period under study, it was common practice to administer 5 gm. of a sulfonamide drug intravenously to all with abdominal wounds immediately on admission to the hospital and to repeat this dose at intervals of 12 to 24 hours thereafter. With the appearance of anuria, this practice was discontinued, and no sulfonamide drug was given intravenously until 12 hours after operation and only after the patient had fully reacted from shock. At the same time, the amount of sulfanilamide dusted into the peritoneal cavity was limited to 5 gm. and the amount in all wounds to 10 gm. That sulfonamide drugs were

a causative factor at least in one case, cannot be refuted. That they were not the only factor except in a few cases, likewise, was evident from subsequent studies. In 30 of the 68 cases in which pigment nephropathy was the direct cause of death and in 14 of the 31 cases in which pigment nephropathy contributed to death, there was no record of sulfonamide therapy, excluding the sulfanilamide powder dusted into wounds at the time of the first aid dressing.

The microscopic observation of a lesion termed hemoglobinuric nephropathy focused attention on blood transfusion as a causative factor. Before the establishment of a blood bank unit in the Mediterranean theater, reactions from mismatched and unmatched transfusions did occur in a few instances. However, anuria continued to develop after the use of group O blood from the blood bank. Then it was thought that the transfusion of a large quantity of group O blood to group A or group B recipients might be responsible for anuria in some of the cases; however, low titer group O blood (containing anti-A and anti-B iso agglutinins in a titer of less than 1 to 120) was used for all except group O recipients, and it was later ascertained[10] that the incidence of pigment nephropathy in the persons of the four blood groups paralleled the relative incidence for persons of the four groups in the general population. In a separate article,[11] a case of Maj. James M. Mason's was mentioned in which a group A recipient received 5,500 cc. of low titer group O blood before and during operation for a thoracoabdominal wound, which involved the removal of one kidney. There was no evidence of insufficiency in the remaining kidney, and the patient made an uneventful recovery. It was likewise demonstrated[12] that the shock occurring in battle casualties was due in most instances to loss of whole blood and that the apparently massive doses of blood used in resuscitation of these patients were excessive in only a few instances. In most cases, determinations of the volume of blood established the fact that not enough whole blood was being used in the resuscitation of these patients. It was also observed that many patients showing gross hemoglobinuria did not always experience renal insufficiency, while, on the other hand, in many of the fatal cases of pigment nephropathy hemoglobinuria was never apparent grossly.

Early in 1944, at the same time that a reduction in the use of sulfonamide drugs was effected, the use of sodium bicarbonate to render the urine alkaline was encouraged. In many cases, it was given by mouth as soon as treatment with sulfonamide drugs was started; in others, it was given intravenously before sulfonamide medication and blood transfusion. Records regarding this treatment were seldom complete, but in the 99 cases of nephropathy the use of sodium bicarbonate was reported in 21 cases.

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[10] Mallory, T. B.: Hemoglobinuric Nephrosis in Traumatic Shock. Am. J. Clin. Path. 17:427–443, June 1947.

[11] Snyder, H. E., and Culbertson, J. W.: Causes of Death in Battle Casualties Reaching Hospitals. Am. J. Surg. 73:184–198, February 1947.

[12] (1) Report, J. J. Lalich, to Commanding Officer, 2d Auxiliary Surgical Group, June 1944, subject: Transfusion Therapy in the Battle Casualty Exhibiting Evidence of Circulatory Failure. (2) Report, J. J. Lalich, to Surgeon, Mediterranean Theater of Operations, U.S. Army, November 1944, subject: Hematocrit and Plasma Protein Findings in Battle Casualties Treated in a Field Hospital.

The hepatorenal syndrome was considered as a mechanism which might account for anuria in some of the cases. The reports of Orr, Helwig, and Schutz[13] constituted the chief source of information for American surgeons concerning renal shutdown associated with trauma. It was apparent, however, that the majority of patients seen did not present evidence of hepatic damage, although such damage was present in no inconsiderable percentage. Review of the microscopic renal observations in the cases reported by Orr and Helwig would lead one to believe that the condition they described was pigment nephropathy.

Lucké[14] reviewed 538 cases in which the disease was fatal, the records and material of which were received at the Army Institute of Pathology during the war. He found the characteristic renal lesion in 11 groups, which included cases in which there were battle wounds, crushing injuries, abdominal operations, burns, reactions from blood transfusion, intoxication due to sulfonamide drugs, heat prostration, malaria due to infection with *Plasmodium falciparum* (black-water fever), poisoning due to a variety of agents, hemolytic anemia, edema, and such unrelated conditions as uteroplacental damage, acute pancreatitis, and rickettsial disease.

With increasing experience with the condition, it became the opinion of many that the severe degree of shock occurring in most of the cases must be responsible at least in part for the development of nephrosis. In the fall of 1944, a board[15] for the study of the severely wounded was appointed by Col. Edward D. Churchill, MC, Consultant in Surgery, Mediterranean theater. This board made elaborate studies, both clinical and laboratory, on battle casualties in severe shock[16] when admitted to forward hospital installations and all observations of practical value were made available immediately in the forward hospitals. Before this time, clinical observation by many and laboratory investigation by Stewart, Lalich, and others had led to the general belief that shock in persons suffering injury in battle was in most cases due to loss of whole blood. The studies of the board confirmed this opinion and defined the exceptions to the rule. It was learned that in the cases in which nephropathy developed the observation of a benzidine-reacting pigment in the specimens of urine was a constant feature. Study of this pigment by a chemical method showed that it was myoglobin in cases of crush injury but that in the other cases it might be hemoglobin or myoglobin or a combination thereof. Except in the cases in which there were crush injuries, it was impossible to predict from the nature of the injury what type of pigment would be seen in the urine. Mallory, a member of the board, observed that it was not possible by micro-

[13] (1) Orr, T. G., and Helwig, F. D.: Liver Trauma and the Hepatorenal Syndrome. Ann. Surg. 110:682–692, October 1939. (2) Helwig, F. D., and Schutz, C. B.: A Liver Kidney Syndrome. Surg., Gynec. & Obst. 55:570–580, November 1932.

[14] Lucké, B.: Lower Nephron Nephrosis. Mil. Surgeon 99:371–396, November 1946.

[15] Members of the Board for the Study of the Severely Wounded were as follows: Lt. Col. Henry K. Beecher, MC, Lt. Col. Fiorindo A. Simeone, MC, Lt. Col. Tracy B. Mallory, MC, Maj. Eugene R. Sullivan, MC, Capt. Charles H. Burnett, MC. Capt. Louis D. Smith, SnC, and Capt. Seymour L. Shapiro, SnC.

[16] Medical Department, United States Army. Surgery in World War II. The Physiologic Effects of Wounds. Washington: U.S. Government Printing Office, 1952.

scopic study of the kidneys to determine whether a lesion had been produced by poisoning due to sulfonamide drugs, mismatched transfused blood, or other factors. Mallory pointed out that the deposit of pigment in the distal convoluted and collecting tubules does not seem to be the first pathologic change in the kidneys. In 11 of their patients who died of injury within 72 hours, only 2 showed pigment casts in significant numbers.

Before the appearance of pigment casts, a fine fat vacuolization of ascending limbs of Henle's loops appears. Mallory stated that this appears in 75 or 80 percent of patients who experienced shock, regardless of whether clinical evidence of renal insufficiency develops or not, and that the process is reversible. He expressed the belief that the pigment casts play no role in the initiation of renal insufficiency following shock but that one cannot state that they have no effect in the later stages of the disease. The dilatation of the renal tubules proximal to the casts and about them would lead to the assumption that they do produce a degree of obstruction, at least in the involved tubules.

CASE REPORTS

Case 1.—An infantryman suffered a perforating wound of the left lower part of the abdomen and the left hip from a machinegun bullet. He was admitted to the battalion aid station 10½ hours later; 6½ hours more elapsed before his admission to a field hospital. At this time, the blood pressure was unmeasurable. He was given 500 cc. of plasma and 2,500 cc. of low titer group O blood prior to operation. A catheterized specimen of urine appeared blood stained. A laparotomy was performed 7 hours after admission and 24 hours after the wound had been incurred, and a laceration of the jejunum and early severe peritonitis were observed. The laceration was sutured; the peritoneum was irrigated with isotonic solution of sodium chloride and 100,000 units of penicillin; and 10 gm. of sulfanilamide were deposited in the peritoneal cavity. The wound at the left hip, which had produced a compound fracture of the greater trochanter, was debrided. He was then given 5 gm. of sodium sulfadiazine intravenously. Treatment with penicillin, 25,000 units every 3 hours, was started on admission. The blood pressure at the end of operation was unmeasurable, but within 2 hours it rose to 100 systolic and 80 diastolic. His postoperative course was characterized by progressive oliguria, edema, uremia, disorientation, and respiratory distress. Death occurred on the eighth postoperative day. On the first postoperative day, he received 500 cc. of blood, 500 cc. of plasma, 1,000 cc. of dextrose in isotonic solution of sodium chloride, and 5 gm. of sulfadiazine. On the second postoperative day, he was given 500 cc. of blood, 2 units of plasma, 2,000 cc. of dextrose in isotonic solution of sodium chloride, and 5 gm. of sulfadiazine. No more sulfadiazine was given and no more blood except 1 pint (about 473 cc.) the day before death. Two days before death, the nonprotein nitrogen in the blood was 91 mg., chlorides 605 mg., and sulfadiazine 13.23 mg. per hundred cubic centimeters. His urinary output on the day of operation was 150 cc., and on successive days it was 200 cc., 350 cc., 300 cc., 600 cc., 400 cc., undetermined, and 75 cc.

At autopsy, the peritoneal cavity contained a small amount of thick grayish yellow foul-smelling pus, and the viscera were plastered to one another and to the parietes by a coating of exudate up to 4 mm. in thickness. The liver was approximately 50 percent heavier than normal, and the capsule was tense beneath the sheet of exudate on its surface. On sectioning, the cut surface was nutmeg brown, with well-defined architectural units. The spleen was doubled in size, and the capsule beneath the exudate was grayish red. The kidneys were moderately enlarged; the capsules stripped readily, revealing surfaces which were darker brown than normal, with fine dark red points and lines scattered throughout.

The cortices were slightly widened; the pyramids were swollen and discolored by brown and red lines paralleling the tubules. The apexes of the pyramids were dark brownish yellow. The lungs did not collapse normally, and their weight was decidedly increased, particularly on the right side. Cut surfaces were moist and released blood-stained mucoid fluid on pressure. There were slightly firm purplish red areas scattered throughout all the lobes, but these were confluent only in the lower parts of the right upper and right lower lobes. Examination of the renal sections showed that the glomeruli were moderately congested; the tubules were slightly dilated. The distal convoluted and collecting tubules contained numerous brown granular and hyaline casts. Many tubules contained desquamated epithelial cells and polymorphonuclear cells. One tubule showed a decided proliferative reaction interspersed with polymorphonuclear cells. Here the inflammatory process extended into the interstitium. There were scattered crystals of a sulfonamide drug within the lumens of the distal tubules. The interstitial tissues contained engorged blood vessels, and there was extravasation of small red cells. Microscopic pathologic diagnoses included pigment nephrosis, hemorrhagic bronchopneumonia, acute purulent perihepatitis, and perisplenitis.

Case 2.—A 21-year-old soldier was injured during a bombing raid when a stone building collapsed on him. He was extricated from beneath a pile of stone after 3⅔ hours and reached an evacuation hospital 15 minutes thereafter. There was no visible evidence of traumatism, and skeletal roentgenograms revealed nothing of significance. His blood pressure was 104 systolic and 74 diastolic, and the pulse rate was 120. The urine was wine colored, with no red cells. Approximately 7 hours after admission, he was given 500 cc. of type O blood and then 1,000 cc. of 5 percent dextrose. Four or five hours later, he went into a state of shock. This was evident by pallor, loss of radial pulse, and no blood pressure. A transfusion was started, but when the hematocrit was observed to be 70 percent it was discontinued, after 300 cc. were given, and dextrose with isotonic solution of sodium chloride substituted. The blood pressure rose to 100 systolic and 80 diastolic. A specimen of urine was chocolate colored. He complained of many points of muscular soreness and tenderness, and the areas were tense and brawny on palpation.

During the succeeding 9 days, he remained oliguric, the daily output of urine ranging from 50 to 100 cc., with an intake of about 3,000 cc. of fluid. Sodium bicarbonate was given daily in 2.5 percent of solution. The patchy muscular induration increased. The urine became normal in color on the third day but still had a positive benzidine reaction. On the sixth day, the face was puffy, and there was pitting edema over the sacrum. The blood pressure was 150 systolic and 110 diastolic. Magnesium sulfate was given intramuscularly. During the next 3 days, the edema increased and the hypertension persisted; epistaxis became frequent; and death occurred with relative suddenness a little less than 10 days after the injury. The level of nonprotein nitrogen in the blood reached a total of 291 mg. and creatinine 12.2 mg. per hundred cubic centimeters the day before death occurred. A check for myoglobin on one specimen of urine early showed a concentration of 588 mg. per hundred cubic centimeters. At autopsy, all muscles appeared paler than normal and scattered throughout the skeletal musculature were many focal areas of traumatic damage. In most instances, these were segments of muscles closely proximate to bone. Larger foci noted were in the flexor group of the left forearm, the left vastus medialis, the lower quarter of the right sartorius, and all of the right soleus. The general pattern was a pigmented grayish white area in the muscles surrounded by a hemorrhagic border. Some of these areas appeared translucent and like fish flesh; others were frankly necrotic, with an opaque slighty grayish infiltration. Some foci appeared almost chalky, and the muscle fibers in the involved areas were friable and easily torn. The kidneys weighed 550 gm. They were symmetrically enlarged, and the vessels of the perirenal fat were engorged. One focus of hemorrhage in this fat was noted at the lower pole of the right kidney. It was entirely extracapsular. The capsules stripped readily and left pale smooth surfaces. The arteries and veins were patent. On sectioning, the cortex was pale and swollen. The surfaces appeared moist;

the pyramids were dark, with a hint of brown in predominant redness. The vessels were not engorged, and no gray zone was present at the corticomedullary junction.[17]

Case 3.—A soldier was wounded in action near Cassino, Italy, by artillery shell burst. He was admitted to an evacuation hospital approximately 4¼ hours later, in good condition and showing no signs of significant loss of blood. In the shock tent, he was given 60 grains (3.9 gm.) of sulfadiazine and 500 cc. of plasma. Thirty minutes later, in the operating tent, the wound of entrance overlying the head of the left femur posteriorly was debrided, and the track followed up toward the anterior-superior iliac spine, where a counterincision was made. A foreign body was removed without difficulty, along with two or three comminuted bone fragments. A penetrating wound of the left forearm was then debrided and the foreign body removed. Both wounds were treated with sulfanilamide powder and petrolatum-impregnated gauze. During the operation with the patient under gas, oxygen, and ether anesthesia, a blood transfusion was started. Later, while the patient was still on the operating table and still under anesthesia, generalized shaking chill, or rigor, began. The transfusion was discontinued and 500 cc. of plasma given. The same blood was matched again and observed to be compatible, and the rest of it was administered without untoward reaction. Following the operative procedure, a catheter was inserted, and 120 cc. of dark blood-stained urine was obtained. From this time on, a catheter was employed every 12 hours. The bladder was still empty after 24 hours. His general condition remained essentially unchanged until approximately 8 hours before death, when he became irrational, breathing became irregular, and increasing pulmonary edema developed. He died approximately 72 hours following operation.

He had received no blood other than that previously noted. In addition to the aforementioned amount of sulfadiazine, he was given 8 gm. by mouth the first 24 hours but none thereafter. Post mortem, the gross examination of the kidneys, ureters, and the bladder failed to reveal any abnormality; however, microscopic examination of the kidneys revealed nephrosis of the lower nephron.

Case 4.—A crush syndrome developed in a soldier, similar to the one presented in Case 3, except that there was no history of low blood pressure at any time during the 4½ days that he lived after injury.

Case 5.—A soldier suffered a perforating wound of the brain, a penetrating wound of the left jaw, and a perforating wound of the right shoulder. He was admitted to an evacuation hospital over 10 hours after the wound had been incurred. On admission, his blood pressure was 130 systolic and 74 diastolic; the pulse rate, 78; and respiration, 20. A roentgenogram of the skull showed that a foreign body 1.6 cm. in size had perforated the skull in the left parietal region, had passed through the parietal lobes, and had perforated the right frontal aspect of the skull, and had come to rest with the bone fragment before it under the scalp. A linear fracture, 12 cm. long, extended backward in the frontal bone on the left, from the depressed fracture entrance. The patient was comatose on admission. He exhibited palsy of the right seventh nerve and spasticity in all extremities. Debridement of the wound of the skull and the brain was performed about 6 hours after the patient's admission to the hospital. In addition, the wounds of the jaw and the shoulder were debrided. He was given 1,500 cc. of blood and 1,000 cc. of plasma during the operation. He remained comatose until his death. He had a relatively high temperature, with increased pulse rate and respiration. He received sodium sulfadiazine intravenously in a dosage calculated to produce a level in the blood of 20 mg. per hundred cubic centimeters. Oliguria developed about 5 days postoperatively, which progressed to complete anuria in 2 more days. Cystoscopy was performed, and the renal pelves were lavaged with sodium bicarbonate solution. Numerous sulfadiazine crystals were observed, particularly in the left renal pelvis. He died 7 days after he was wounded. Microscopic observations at

[17] The report of the microscopic study was not available in this case, but it may be said that essentially the same picture was seen in patients with crush injury as in those with pigment nephropathy resulting from transfusion, poisoning due to sulfonamide drugs, and wounds attended with severe shock.

autopsy included indications of encephalomalacia, bronchopneumonia, and pigment nephrosis.

Case 6.—A soldier was wounded in action by a high explosive shell fragment 1 or 2 days before admission to an evacuation hospital. The exact date and the time of his wounding on Mount Porchia, Italy, were unknown. On admission, he was semistuporous and showed changes in his reflexes, and the roentgenogram showed depressed fracture of the right parietal bone, with a large bone defect and fragments of bone and metallic foreign bodies driven into the right cerebral hemisphere. The operative risk was considered poor, and the patient was given 500 cc. of plasma before operation, 500 cc. of blood during operation, and 500 cc. of blood shortly thereafter. Operation was performed under block anesthesia with procaine hydrochloride approximately 8 hours after his admission to the hospital. Partial craniectomy, with thorough debridement of the wound of the brain and dural repair, was accomplished. At termination of the operation, the patient was sent to the ward in satisfactory condition, with a blood pressure of 120 systolic and 70 diastolic, a pulse rate of 120, and a temperature of 100.2° F. Postoperatively, he received 10 gm. of sodium sulfadiazine intravenously, in two doses of 5 gm. each in the first 24 hours and 5 gm. intravenously in divided doses in the second 24 hours. Subsequently, he received sulfadiazine, 6 gm. daily by mouth, through the eighth postoperative day. He also received one unit of concentrated plasma twice daily for 8 days and four blood transfusions postoperatively. He was never entirely rational or lucid, but at times he responded moderately well to questions and talked coherently. Four days postoperatively, the patient had a crisis, characterized by clonic contractions of the right side of the body and face for a few seconds, followed by twitching for several minutes and a sudden rise of temperature to 107° F; the pulse rate was 160 and respirations, 52. All subsided quickly. His daily temperature, aside from this one episode, was from 102° to 103° F. On the ninth postoperative day, the patient was much weaker and drowsier and responded poorly to questions. He showed hemiplegia and facial paralysis on the left side, which had been present all along, plus weakness of several cranial nerves. Treatment with sulfadiazine was discontinued on this date, and his condition was considered critical. The next day he was much worse, presenting dyspnea, cyanosis, tachycardia, decided pulmonary congestion, jaundice, and coma. A diagnosis of terminal bronchopneumonia was made; the cause of the jaundice was not clear. At post mortem examination, it was noted that the common duct and larger branches were not obstructed and that the gallbladder was not enlarged. On sectioning, the hepatic tissue appeared to be deeply jaundiced, and the appearance was somewhat suggestive of a diffuse necrotic process. The parenchyma of both kidneys appeared to be within normal limits; the kidneys were about normal size, and the capsules stripped normally. The pelves of the kidneys were stained with bile, and the mucosa contained numerous pinpoint hemorrhages. No crystals were evident. There were no signs of infection in the wound of the brain. The diagnoses, based on gross pathologic studies, were nonobstructive jaundice, the cause of which was undetermined; bronchopneumonia; and hepatitis. The report of microscopic examination of the section of the liver was not available, but the following diagnoses, based on microscopic studies, were made: (1) Bronchopneumonia, (2) jaundice, and (3) slight hemoglobinuric nephropathy. The significance of the latter diagnosis is not entirely clear. This patient was carefully studied, and his daily urinary output was over 1,000 cc., except on the day of his death. It is perhaps incorrect to assume that hemoglobinuric nephropathy contributed to death in this case.

Case 7.—A soldier was admitted to a field hospital approximately 1 day after being wounded by enemy shellfire near Montecatini, Italy. He suffered compound fractures of the left tibia and fibula in the middle third, a compound fracture of the left clavicle, a compound fracture of the left scapula, and multiple penetrating wounds of the left buttock. All of his wounds were debrided under open drop ether anesthesia in the field hospital. Six days later, he was evacuated to an evacuation hospital, where he died 1 hour and 20 minutes after admission. There was nothing further in his record concerning his clinical course. Post mortem examination was done, and it was observed that both kidneys were enlarged, that

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the cortex was pale and swollen and irregular in both kidneys, and that the capsule stripped easily. A diagnosis, based on gross pathologic studies, of nephrosis was made, the cause of which was unknown. There were no microscopic observations in this case. Also presented were bilateral pleural effusion, a hematoma in the upper lobe of the left lung, and pulmonary congestion and edema, as well as the wounds previously noted. While there was no evidence of shock recorded, it probably should be stated that the record was too inadequate to permit the conclusion that shock did not exist at one time or another.

The condition described as pigment nephropathy, or lower nephron nephrosis, occurs with a variety of conditions. In battle casualties, the renal damage is probably dependent on renal ischemia plus the excretion of pigment. The renal ischemia is vasoconstrictive in origin and occurs in patients in a state of shock and with related conditions. Whether or not the vasoconstriction is induced by a toxin elaborated from damaged tissues or by reflex vasomotor stimulation has not been definitely established. The pigment excreted may be myoglobin or hemoglobin. The source of the hemoglobin may be from transfused blood, intravascular hemolysis, and probably from other sources. The role of infection has not been clearly defined and should be made the subject of investigation. The influence of the various anesthetic agents should be studied.

Treatment should be prophylactic. Shock should be combated vigorously, with prompt restoration of the volume of blood to normal. This should be accomplished with the proper medium, which for most battle casualties is whole blood. Treatment with oxygen is of value in combating anoxia, which must result from vasoconstriction in the renal circulation. Injudicious use of sulfonamide drugs should be avoided, and discontinuance of their use in conditions predisposing to nephropathy should be considered. Dehydration should be avoided when possible and otherwise corrected as promptly as possible. Thorough surgical removal of all devitalized tissue and foreign bodies and provision of adequate drainage to infected areas is important.

CHAPTER VIII

Casualty Survey, Cassino, Italy

Allan Palmer, M.D.[1]

Casualty surveys of civilians killed or injured in air raids in England had yielded detailed information about the wounding power of bombs and about the relative value of different measures of protection. The advantage of such surveys was that the investigator could conveniently study not only the casualties themselves but also the circumstances under which they were injured.

Useful information had also been obtained in the past from surveys of battle casualties undergoing treatment in base hospitals. However, this information was limited since the casualties seen represented only a small and usually a selected proportion of the total.

It had long been felt that more useful information could be obtained by studying the casualties incurred by selected units engaged in a specific operation for which full details were available and, particularly, if such a survey could be made further forward than the base hospitals. While the survey had to be limited[2] because of shortage of time and personnel, it has shown that studies of a similar kind could be successfully carried out, and it has also provided useful guides for further procedures.

The scene of the battle was about 75 miles southeast of Rome along a 6-mile sector, the front of which lay along the Rapido River (fig. 264) immediately south of the town of Cassino (fig. 265). This front flanked a railroad and a main road to Rome (Highway No. 6, fig. 266). Figures 267 and 268 show the terrain in the vicinity of Monte Lungo with the highly advantageous enemy defensive positions.

Operations to bridge and advance across the Rapido River were begun during the night of 19 January 1944 and were successfully completed on 12 May.

[1] In November 1943, Maj. Allan Palmer, MC, was relieved of his assignment as chief of the laboratory service, 30th General Hospital, European theater, for the purpose of joining Prof. Solly Zuckerman, C.B., F.R.S., in the Mediterranean theater for indoctrination in field casualty survey methods. Professor Zuckerman, as scientific advisor to the Allied Air Forces leaders, held an honorary commission as Group Captain and later was the commanding officer of a component of the Royal Air Force known in the Mediterranean theater first as the Special Air Mission and later as the Bombing Survey unit. When the Secretary of War established the U.S. Strategical Bombing Survey in 1944, Zuckerman's organization finally became known as the British Bombing Survey Unit. Major Palmer was one of the two American scientific observers attached to this unit. With the help of a Royal Air Force medical officer, Squadron Leader C. Spicer, from Professor Zuckerman's unit, and an American medical officer, Maj. (later Lt. Col.) Roberto F. Escamilla, of the 59th Evacuation Hospital, who was detailed by the Seventh U.S. Army surgeon, and in liaison with General Martin, Fifth U.S. Army surgeon, Major Palmer conducted the specimen survey of 100 battle casualties sustained by the Fifth U.S. Army during the Rapido River conflict south of Cassino from 20 to 27 January 1944.—J. C. B.

[2] While it is true that this survey covers only relatively few casualties, incurred during a short interval of the total campaign, it is an excellent demonstration of the organization and conduct of a casualty survey and the scope of information available.—J. C. B.

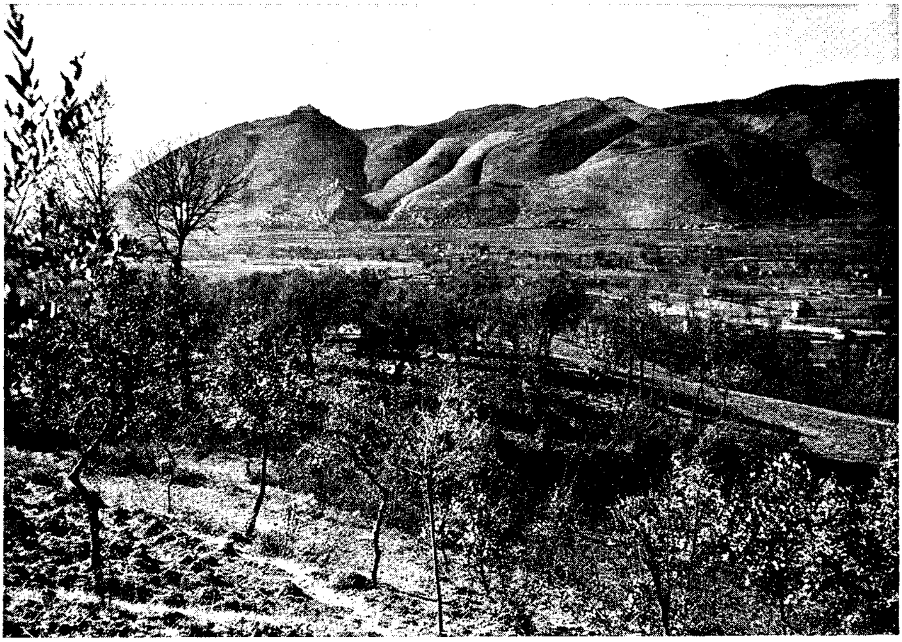

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FIGURE 264.—Rapido River valley area, Italy, 6 February 1944. German's Gustav Line. Monte Cassino with Benedictine monastery on the summit of the hill (left) and Cassino at the base.

The main U.S. troops engaged in the operation were the 141st and 143d Infantry Regiments, 36th Infantry Division, and the 34th Infantry Division, Fifth U.S. Army.

Fighting was of the static kind and was confined for many days to an isolated area of mountainous country, as shown in figures 269 and 270. Allied and enemy forces were not visible to each other, and there was little small arms fire. Most wounds were inflicted by artillery and mortar shells and by landmines. The bulk of the fighting with the casualties sustained, occurred during the hours of darkness, especially when river crossings were attempted. In general, the enemy's guns and mortars were zeroed in (fig. 271) to cover the area traversed by U.S. troops, and periodically a harassing fire was laid down, inflicting a very large number of casualties as wave after wave of troops advanced in the region of the river.

The U.S. Army units engaged in this action had obtained previous experience of this type of warfare in operations which had resulted in the capture of three mountain strongholds, Trocchio, Porchia, and Lungo. These hills lay to the rear of the Rapido front and between U.S. troops and Highway No. 6. The mountainous terrain necessitated the use of mules for the transport of supplies and ammunition.

SC 239682

FIGURE 265.—Town of Cassino, Italy, 6 February 1944. The Cassino castle is on the small hill in the foreground and the Benedictine monastery is on the summit.

The stubborn resistance by the enemy in his attempts to maintain control of Highway No. 6, and the considerable advantage of the terrain and entrenched enemy positions, made the fighting the bitterest experienced by U.S. troops in the whole Italian campaign. During the later stages of the campaign, concentrated aerial bombardment assisted in the capture of Cassino (figs. 272 and 273).

MEDICAL FACILITIES AND EVACUATION OF CASUALTIES

Figure 266 shows the layout of the medical installations which served the Fifth U.S. Army front in the Cassino area. They included six evacuation and three field hospitals and two clearing companies, in the following order:

11th Field Hospital (near Venafro)
422d Field Hospital (French)
16th Evacuation Hospital
11th Evacuation Hospital (Semimobile)
602d Medical Clearing Company (Separate)
38th Evacuation Hospital
94th Evacuation Hospital (Semimobile)
15th Evacuation Hospital (Semimobile)
8th Evacuation Hospital
601st Medical Clearing Company (Separate)
10th Field Hospital

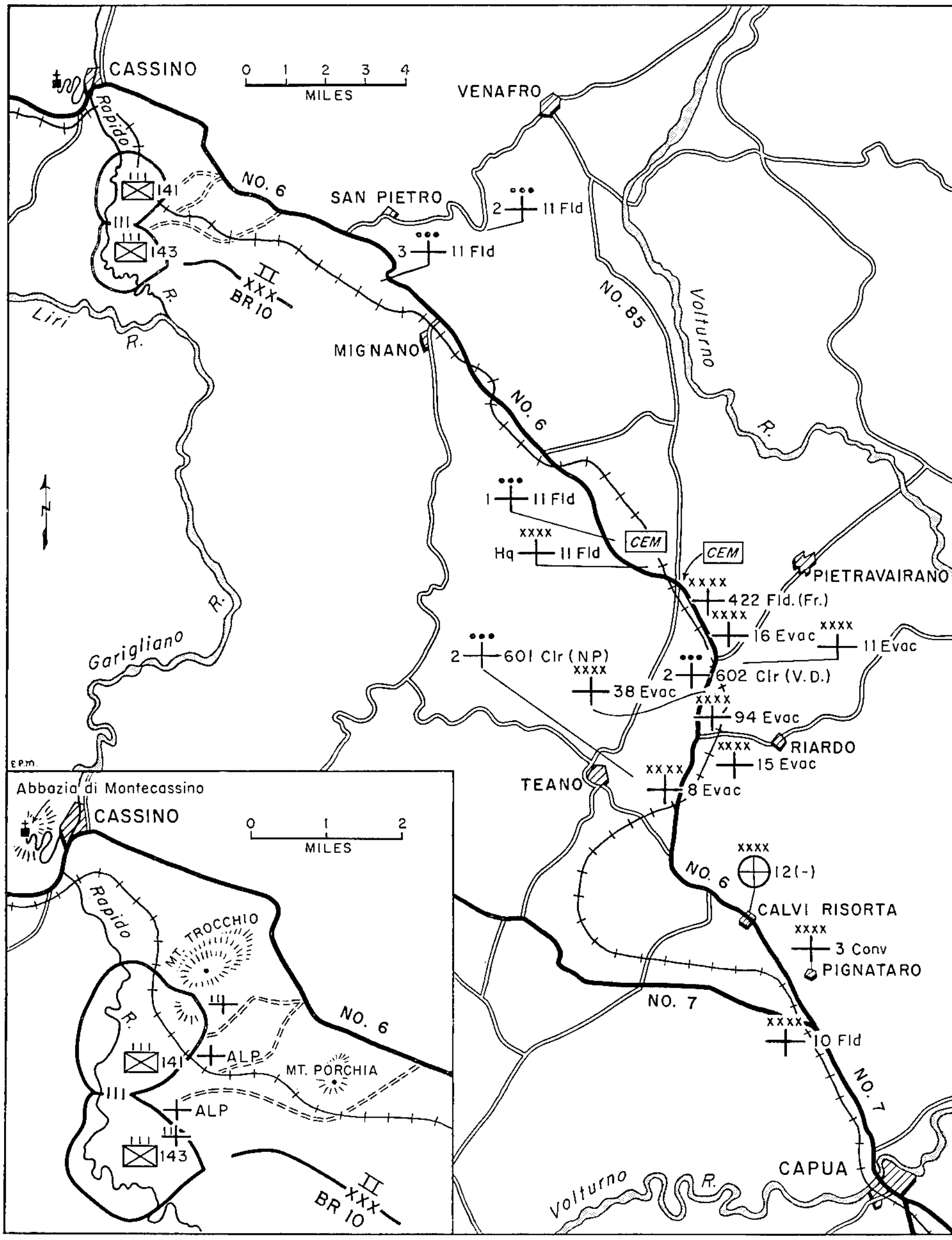
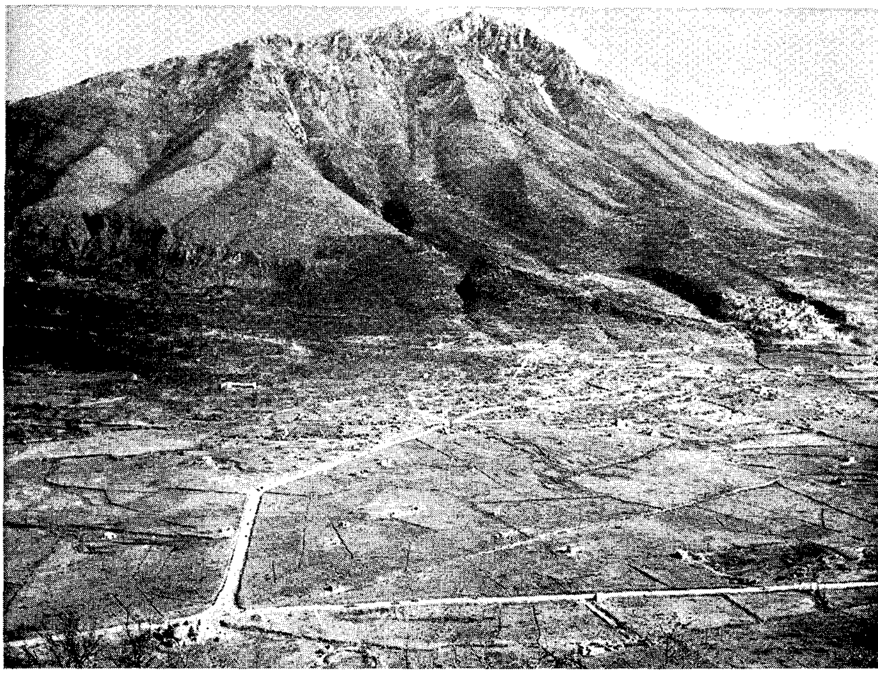


FIGURE 266.—Map of the area in which the casualty survey was conducted. The route of evacuation and location of U.S. medical installations are indicated.



SC 188154

FIGURE 267.—View from center of Monte Lungo, Italy, 18 February 1944. (Center) Monte Sammucro. (Right) San Pietro. Highway No. 6 is along the bottom and the San Pietro road up center to San Pietro. This tremendously advantageous defensive position held by the enemy for some weeks accounted for many casualties sustained by the Fifth U.S. Army. Note shell craters in the foreground.

Casualties were carried out of the actual battle zone by litter squads and jeeps. The ALP (ambulance loading points) (fig. 266) were located immediately outside the battle zone. The routes followed by the ambulances to Highway No. 6 are also shown in figure 266. One of them consisted of a railway track from which the rails had been removed.

Casualties were sorted in the vicinity of the ALP. Those whose main injuries were either cranial, thoracic, or abdominal were sent daily to the 15th and 38th Evacuation Hospitals. The majority of other casualties were evacuated alternately to the 11th and 94th Evacuation Hospitals on even-numbered days and to the 8th and 16th Evacuation Hospitals on odd-numbered days. On occasions when full loads could not be made up with cranial, thoracic, or abdominal casualties, all types of casualties were taken to the 15th and 38th Evacuation Hospitals.

SC 184383

Figure 268.—German emplacements south of Monte Lungo, Italy, 26 December 1943. Tank trap and approaches where Germans removed everything but stumps, then mined the field.

The dead, including some German dead, were removed from the casualty areas by the Graves Registration Service and taken to one of the two burial grounds (CEM, fig. 266) which were located in advance of the evacuation hospitals.

Within a few minutes after they were wounded, men who could not help themselves were given first aid either by a medical aidman or by one of their fellow soldiers. Walking casualties were then directed to the nearest aid station or left where they had fallen to be transported later by litter.

The following information on the time taken to evacuate casualties from the battle zone was provided by Col. John W. McKoan, Jr., MC, Commanding Officer, 8th Evacuation Hospital, who had made a special study of 100 casualties received at his hospital on 21 January, the second day of the Rapido River operation. The average time taken for a casualty to reach the nearest aid station after wounding proved to be 5 hours and 55 minutes. Some men had to be brought from the far side of the river which they had already crossed, and a few such casualties did not reach aid stations for a period of 24 hours or even longer. The average time from aid station to clearing station was 2 hours and 48 minutes and from clearing station to evacuation hospital, 58 minutes. The average total time required from the time of injury to entry into a hospital for definitive treatment was 9 hours and 41 minutes.

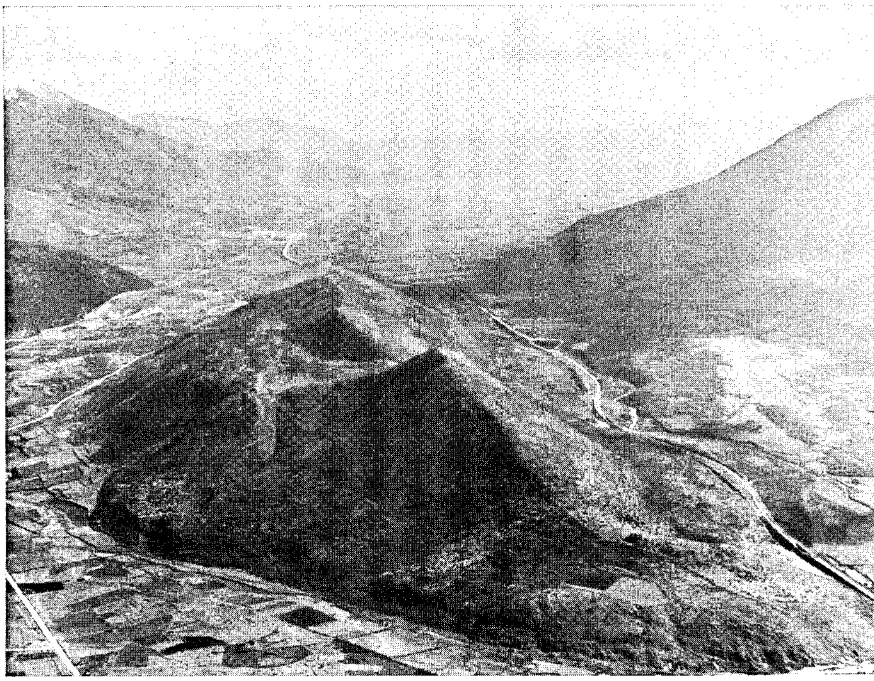


FIGURE 269.—Aerial view of Monte Lungo (Cassino-Mignano-Esperia area), Italy, 1944, showing the rugged terrain.

ANALYSIS OF CASUALTIES

An initial survey of the problem indicated clearly that, with only three medical officers available to carry out the work, it would be impossible to do more than survey a sample of those casualties who reached the 8th and 38th Evacuation Hospitals. While it was realized that this procedure would impose a bias on the information collected, it was hoped that the missing factors in the analysis could be obtained later by a study of central records. The whole complex of data which would have to be collected was as follows:

1. Strength of forces engaged in the operation during the relevant period.
2. Total number of killed and wounded for the two units concerned (the 141st and 143d Infantry Regiments).
3. Data about the causes of death and regional distribution of wounds in the dead. These data were being collected by the Graves Registration Service on special forms for transmission to Washington, D.C. However, the EMT (emergency medical tags), filled out by the medical aidman on the battlefield and then attached to the body of the dead soldier, was the only recorded information about wounds and cause of death. The bodies were buried fully clothed without preliminary examination by a medical officer.

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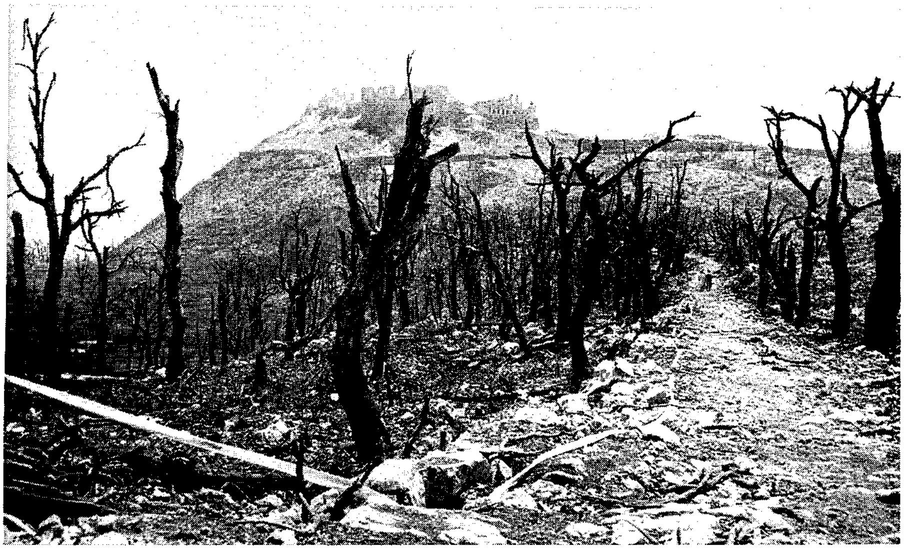
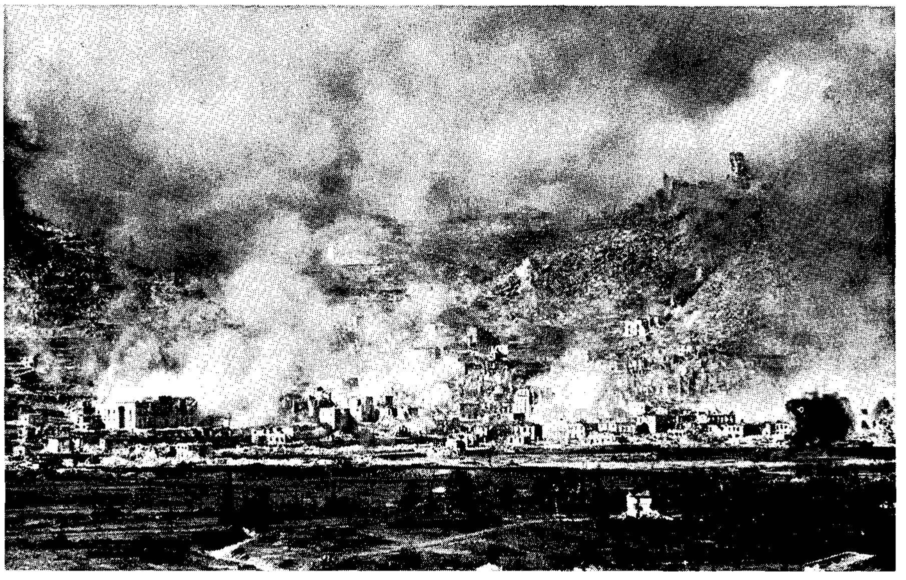
FIGURE 270.—Cassino area, Italy, 6 March 1944. The terrain traveled by the mortar squads is tough, rocky, and hard to get over.



U.S. Army photo

FIGURE 271.—Approach to Monte Cassino, showing the German's excellent line of fire, 30 May 1944. The trees were parched by shellfire and bombings. White tapes indicate the limit to which the terrain has been cleared of landmines. Ruins of Benedictine monastery in background.



SC 188096

FIGURE 272.—Town of Cassino being destroyed, 15 March 1944. In one of the war's most concentrated air bombings, the town of Cassino was completely destroyed. German-held Cassino had long blocked the Allied advance toward Rome.

SC 189950

FIGURE 273.—Cassino area, Italy, 18 May 1944. Ruins of Cassino castle, "Hangman's Hill," towers above the city.

4. Details about those casualties from the two units concerned who were selected by the clearing companies for treatment in the 15th and 38th Evacuation Hospitals, which dealt predominantly with injuries of the head, thorax, and abdomen. A daily report of casualties, which includes a statement about the regional distribution of wounds, was made by all hospitals to the Surgeon, Fifth U.S. Army. A study of these reports, together with an analysis of the records of the cranial and trunk casualties, and of the dead, of the two units concerned would complete the casualty picture for these two infantry regiments during the first week they were engaged in the crossing of the Rapido River (20–27 January).

A few casualties from other units which were engaged in the same operation as the 141st and 143d Infantry Regiments were also studied.

During the survey period (20–27 January 1944), 100 WIA (wounded in action) casualties were interviewed—73 at the 8th Evacuation Hospital and 27 at the 38th Evacuation Hospital. This group of casualties consisted of 6 officers and 94 enlisted personnel. The majority of the casualties were able to give their approximate geographical position in relation to the Rapido River, state their assigned duty at the time they were wounded, and describe and identify the type of enemy weapon responsible for their wounds. Of the casualties, 90 were hit while advancing toward the enemy. The majority were engaged as infantry troops armed with either rifles or machineguns, and a smaller number were wounded while carrying a footbridge or a boat or when they were in a boat. Of the remaining 10 men, 5 were on guard duty and the other 5 were wounded while engaged in carrying the dead from the firing zone.

Effect of Posture on Wounds

Of the 90 casualties who were hit while advancing toward the enemy, 40 received their wounds when standing erect, and the remaining 50 men were hit either when lying or kneeling or after they had taken cover in a ditch or a foxhole. The following tabulation lists the incidence of single and multiple wounds in relation to the position of the casualty:

	Number
Standing:	
Single wounds	18
Multiple wounds	25
Kneeling or lying:	
Single wounds	38
Multiple wounds	15

The tabulation indicates very clearly that men lying down, or otherwise taking cover, are less likely to receive multiple wounds than men standing erect.

The difference in the incidence of multiple wounds in soldiers taking simple cover and those not taking cover is highly significant statistically according to the chi-square test which gives $\chi^2=7.84$ (n-1, $P<0.01$).

Weapons Responsible for Wounds

Almost all of the casualties who were interviewed felt certain that they knew what type of weapon had caused their wounds. Table 170 shows the number of casualties caused by different weapons and the incidence of fractures.

The preponderance of wounds due to artillery and mortar shells and mines is what would be expected in operations of the kind studied.

TABLE 170.—*Incidence of fractures in 100 casualties, by causative agent*

Causative agent	Number of casualties	Number of fractures
Shell:		
Artillery	42	9
Mortar	31	10
Artillery or mortar	3	2
Landmine	13	3
Hand grenade	9	2
Bullet:		
Machinegun	1	1
Rifle	1	----------
Total	100	27

The sizes of the fragments responsible for wounds were estimated from X-rays in 28 cases. The weights of the fragments were estimated in grams from their linear dimensions. A large series of X-rays of fragments of known weight were available as a standard.

All but 1 of the 28 casualties in question had been wounded by either artillery- or mortar-shell fire. The exceptional case had been wounded by a landmine. Table 171 summarizes the information obtained on this point and also gives the distances from the burst at which the casualties stated they were injured. Of the 28 casualties, 10 sustained injuries only from fragments weighing 1 gm. or more, while another 5 were hit by smaller fragments in addition to hits by fragments of the larger size. The remaining 13 casualties were injured by fragments weighing less than 1 gm. and in 4 of these only fragments of less than 50 mg. were found.

Regional Distribution of Wounds

Table 172 shows the regional incidence of wounds in the total sample studied. Since four of the casualties had no obvious external injury, their wounds have been included in the table as injuries of the head.

Although none of the casualties seen had been wounded in more than three regions of the body, the number of wounds in any one casualty was often

TABLE 171.—*Distribution and weight of fragments in 28 casualties, by distance from shellburst*

Distance from shellburst (in feet)	Weight of fragments				Total fragments	Casualties
	1-50	50-250	250-1,000	1-5		
	Mg.	*Mg.*	*Mg.*	*Gm.*	*Number*	*Number*
Artillery shells:						
0–10	17		8	7	32	5
10–20	3	7	7		17	2
20–30				1	1	1
30–40						
40–50						
Over 50			4	2	6	3
Total	20	7	19	10	56	11
Mortar shells:						
0–10	48	21	12	2	83	8
10–20	1	1	2		4	3
20–30				1	1	1
30–40						
40–50	6				6	1
Over 50	2			5	7	3
Total	57	22	14	8	101	16
Landmine, 0–10	2				2	1
Total	2				2	1
Grand total	79	29	33	18	159	28

TABLE 172.—*Distribution of 133 single and multiple wounds in 100 casualties, by anatomic location*

Anatomic location	Single wound	Multiple wounds		Total wounds	
		2 regions involved	3 regions involved	Number	Percent
Head	20	5	1	26	19. 5
Thorax	5	8	1	14	10. 5
Abdomen and scrotum		8	1	9	7. 0
Extremities:					
Upper	17	11	2	30	22. 5
Lower	28	23	3	54	40. 5
Total	70	55	8	133	100. 0

as many as six or eight. Table 172 also includes several cases in which men were wounded either in both upper or in both lower extremities.

Only 4 of the 100 casualties required amputations. In two, toes had to be removed because of compound fractures due to shell fragment wounds of the foot. The other two casualties were men who had to have a lower limb removed because they had stepped on a landmine. One of the two was a squad leader who was advancing with a mine detector which did not respond to the mine which caused his injury. This casualty thought the mine probably had a plastic case.

Blast Injuries

The blast pressures necessary to cause injury to the lungs are only likely to be experienced close to the burst of large bombs at distances where severe or fatal injuries from fragments are almost certain to occur. Since artillery shells have a very much lower charge-weight ratio than bombs (a 155 mm. shell only contains 4.8 pounds of explosive), the chances of receiving blast injuries to the lungs without serious fragment injuries are even more unlikely from shellfire than from bombs.

There is no reliable evidence that so-called blast concussion is a direct consequence of the impact of a blast wave on the head. Cranial symptoms, amnesia, and mental confusion are probably due to blows on the head from flying debris or from sudden body displacement. Rupture of the eardrums, however, occurs at very much lower blast pressures than does lung damage, and it is the most sensitive indicator of injury due to blast. In the group of casualties surveyed, there were no instances of damage to the lungs. In 15 casualties, one or both eardrums had been ruptured. Of these men, 11 had also received other injuries from fragments and only 4 had ruptured eardrums as their sole injury.

Of these 15 casualties, 13 were standing erect or had their head and shoulders exposed when they were injured. The other two, although apparently lying protected in slit trenches, were also close enough to the shellburst to experience earth movement, displacement, and partial burial by loose earth nearby. The stated distances (in feet) at which the casualties sustained a blast injury from bursting projectiles is as follows:

Distance from burst (feet):	*Number of casualties*
0–5	9
5–10	2
10–15	1
15–20	1
20–25	1
Unknown	1
Total	15

It is a remarkable fact that 11 of the 15 casualties were within 10 feet of bursting projectiles and sustained injury due to blast but escaped fatal fragmentation wounds.

Casualty Rates

When a small group of casualties is surveyed, the probability of an incident being reported is proportional to the number of casualties it involves or, if wounded men only are reported, to the number of wounded. Having recognized that in this survey an individual incident may be reported more than once, it is necessary to make use of Haldane's method for correcting for this factor. By making use of his formula

$$\frac{C-N}{T-N}\pm\sqrt{\frac{C-N\times T-C}{(T-N)^3}}$$

where N equals the number of incidents reported, C the number of casualties (killed and injured grouped together) and T the total number of men exposed to injury, it is found that the estimated casualty rates from artillery shells is 26.5±2.85 percent. The estimated casualty rate from mortar shells is 28.5±2.25 percent. These rates do not differ significantly from each other.

Table 173 summarizes these and the casualty rates estimated for the same two weapons in previous casualty surveys.

Excluding the American casualties at Cassino, it would thus seem that Allied artillery and mortar were both more efficient than those of the enemy. Such a conclusion would only be justified, however, if it could be assumed that the tactical use of both weapons was the same on both sides. American casualties from enemy mortar shells at Cassino are of the same order as those inflicted by the enemy in other theaters and significantly fewer than enemy casualties from the same weapon. On the other hand, American casualties due to enemy artillery at Cassino are significantly greater than Allied casualties have been in other theaters and are of the same order as U.S. soldiers have inflicted upon the enemy by that weapon.

TABLE 173.—*Estimated casualty rates from Allied and enemy artillery and mortar shells*

Men at risk	Area	Probability of becoming a casualty from—	
		Artillery shells	Mortar shells
		Percent	*Percent*
New Zealanders	Tunisia	16. 87±1. 88	26. 30±1. 83
English	do	18. 18±5. 81	39. 74±5. 54
Enemy	do	25. 51±3. 11	60. 00±9. 80
Americans	Cassino	26. 5 ±2. 85	28. 5 ±2. 25

NOTE.—Statistics were obtained by author while serving as scientific observer with Professor Zuckerman (see footnote 1, p. 531).

As already emphasized, this casualty survey was initiated to discover whether useful and complete information could be obtained in the battle area. While this objective was not achieved in the present case, the investigation has definitely shown that it could be in a future survey, if special arrangements were made in advance to obtain from central records a complete picture of the tactical problem and of the casualties incurred and if the survey itself were adjusted in advance to the size of the staff available to carry out the work.

The advantages of surveying casualties in the forward evacuation hospitals and of examining the dead at their burial grounds are obvious. In these locations, complete casualty data for a specific tactical operation, pertaining to the uninjured, slightly and severely wounded, and the dead can be obtained before the various types of casualties are dispersed, before original X-rays are separated from the casualties, before memory of specific details of incidents is clouded by time or colored by self-interest, and before the dead are buried and lost to detailed examination.

CHAPTER IX

Survey of Battle Casualties, Eighth Air Force, June, July, and August 1944

Allan Palmer, M. D.

The need for information regarding causes of death in KIA (killed in action) battle casualties resulted in the organization of the Medical ORS (Operational Research Section), Professional Services Division, Office of the Chief Surgeon, ETOUSA (European Theater of Operations, U.S. Army). Maj. Allan Palmer,[1] MC, was appointed chief of the section on 1 June 1944.

The purpose of the Medical ORS was to investigate battle casualties from an operational point of view in order to evaluate more accurately the wounding power of various weapons and the effectiveness of protective measures. At the start, it also seemed that information would be obtained which would be of value and interest to officers, not only in the medical but also in the other services. It was postulated that the machinery for collecting data provided adequate liaison with the various branches of the Armed Forces.

Aside from occasional accidents or special incidents (appendix G, p. 827) in the United Kingdom, which were investigated by the Medical ORS, the first operational project to be dealt with was a survey of battle casualties sustained by the heavy bombardment groups of the Eighth Air Force. The survey was carried out with the cooperation of Brig. Gen. Malcom C. Grow, USSTAF (U.S. Strategic Air Forces) surgeon, the Eighth Air Force Operational Analysis Section, the Ordnance Department, the Royal Air Force, and the Royal Canadian Air Force. A period of 3 months was taken as the time during which the day operations of the Eighth Air Force might yield a satisfactory sample of casualty data for study. The 3 months chosen were June, July, and August 1944 (D−5 to D+86). In September 1944, additional personnel were provided by the Army Air Forces, Air Technical Service Command, for a 3-month continuation of the study which was to include examination of KIA casualties from the Ninth Air Force and Troop Carrier Command.

An ideal casualty survey would provide complete information about all battle casualties and about all individuals exposed to risk, irrespective of the

[1] Following the completion of the Eighth Air Force casualty survey, Major Palmer participated in and reported on a ground force battle casualty survey. This survey was conducted with the Third U.S. Army's XII Corps during the last 2 days of the war in Europe.

Based on the experience he had gained in collecting missile casualty data, Major Palmer prepared a draft of a proposed table of organization and equipment for the establishment of a casualty research detachment.—J. C. B.

severity of injury. The points which pertain to such a survey of aircrew battle casualties follow.

1. Strength of forces engaged in operations for the survey period.—(1) Bombardment divisions and groups taking part in operations; (2) types and number of aircraft and combat personnel involved, such as "man-combat missions" carried out; and (3) hospitals serving the Eighth Air Force.

2. Losses.—(1) Aircraft and personnel about which no information could be secured because of failure to return from enemy territory; and (2) casualty data, including the causes of death and regional distribution of wounds, fractures, and amputations in the personnel killed or wounded by enemy gunfire and returned to the United Kingdom in aircraft, which could be obtained from post mortem examination of the killed, interrogation and X-ray examination of the wounded in hospital, survey of "Care of Flyer" reports and group operations at AAF (Army Air Force) stations, and identification of missiles.

3. Battle damage data pertaining to aircraft in which casualties were sustained.—This information would be of the greatest importance for the identification of the weapon causing wounds in cases where the responsible missile was not retained by the casualty. As far as protection to personnel is concerned, a knowledge of the relative frequencies of hits by enemy missiles on aircraft bearing casualties, from various directions, would enable one to place protective armor more advantageously in the aircraft or on aircrew personnel.

4. Flight formations.—The formation of heavy bombers in flight should be studied from the point of view of risk to combat crew personnel.

COLLECTION OF DATA

Strength of Forces

The 40 heavy bombardment groups of the Eighth Air Force, divided into 3 divisions, are listed in table 174.

All the groups of the 1st Division were composed of B–17 aircraft and those of the 2d Division, of B–24 aircraft. Five groups of the 3d Division (34th, 486th, 487th, 490th, and 493d) were originally composed of B–24 aircraft but were changed to B–17's on 24 August, in mid-July, on 1 August, on 18 August, and on 18 August, respectively. Thus, the 3d Division also consisted entirely of B–17 aircraft on and after 24 August. Tables 175 and 176 give a summary of Eighth Air Force heavy bomber day operations, by divisions and man-combat missions, for the 3 months' period of this survey. These data were obtained through the Office of the Surgeon, USSTAF. The total number of aircrew personnel taking part in Eighth Air Force heavy bomber day operations is given in terms of "man-combat missions," the

average crew of a B–17 being 9 and the average crew of a B–24 being 10. Thus, a total of 69,682 sorties corresponds to a total of 657,096 man-combat missions for the 3 months' period.

TABLE 174.—*Eighth Air Force heavy bombardment groups, by divisions*

Group 1st Division	Group 2d Division	Group 3d Division
91st	44th	34th
92d	93d	94th
303d	389th	95th
305th	392d	96th
306th	445th	100th
351st	446th	385th
379th	448th	388th
381st	453d	390th
384th	458th	447th
398th	466th	452d
401st	467th	486th
457th	489th	487th
	491st	490th
	492d	493d

TABLE 175.—*Distribution of 69,682 Eighth Air Force heavy bomber (B–17, B–24) day operations for the period 1 June to 31 August 1944, inclusive, by divisions*

Division	Number of sorties	Aircraft missing in action [1]		Aircraft returning from enemy territory [2]	
		Number	Percent	Number	Percent
	B–17's				
1st	23, 488	237	1. 01	23, 251	98. 99
3d	16, 236	153	. 94	16, 083	99. 06
Total	39, 724	390	. 98	39, 334	99. 02
	B–24's				
3d	5, 510	31	. 56	5, 479	99. 44
2d	24, 448	272	1. 11	24, 176	98. 89
Total	29, 958	303	1. 01	29, 655	98. 99
Grand total	69, 682	693	. 99	68, 989	99. 01

[1] Casualty data are not available.
[2] Casualty data are available.

TABLE 176.—*Distribution of 657,096 man-combat missions, 1 June to 31 August 1944, inclusive, by Eighth Air Force heavy bomber (B–17, B–24) day operations*

Aircraft	Sorties		Man-combat missions	
	Number	Percent	Number	Percent
B–17:				
Missing in action [1]	390	0. 98	3, 510	0. 98
Returning from enemy territory [2]	39, 334	99. 02	354, 006	98. 99
Total	39, 724	57. 00	357, 516	54. 4
B–24:				
Missing in action [1]	303	1. 01	3, 030	1. 01
Returning from enemy territory [2]	29, 655	98. 99	296, 550	98. 99
Total	29, 958	43. 00	299, 580	45. 6
Grand total	69, 682	100. 00	657, 096	100. 0

[1] Casualty data are not available.
[2] Casualty data are available.

The medical installations which served the Eighth Air Force during the period, in addition to sick quarters at each AAF station, were the 1st, 7th, 65th, 91st, 97th, and 184th General Hospitals and the 49th, 121st, 136th, 231st, 280th, and 303d Station Hospitals.

Losses

Of the 69,682 sorties in which 657,096 man-combat missions were accomplished, 693 aircraft (0.99 percent) and 6,540 aircrew personnel (1.00 percent or 10.0 per 1,000) were MIA (missing in action), leaving a balance of 650,556 man-combat missions in 68,989 aircraft, from which battle casualty data were available for survey. The casualty survey study pertained specifically to battle casualties resulting from enemy gunfire, sustained by the personnel carrying out and returning from a total of 650,556 man-combat missions.

A few incidental facts were collected in relation to the 6,540 aircrew personnel MIA during the 3 months. Followup records at Eighth Air Force headquarters showed that, for the first 8 months of 1944, 2 out of 5 (40 percent) MIA personnel were possibly KIA and 3 out of 5 (60 percent) were known to be WIA (wounded in action), prisoners of war, or evaders.

By arrangements through official channels, all KIA aircrew battle casualties returning to the United Kingdom in heavy bombers, as well as all those dying in hospital within 24 hours of entry or before surgical treatment, were brought for examination to the Medical ORS laboratory, located on the grounds of the

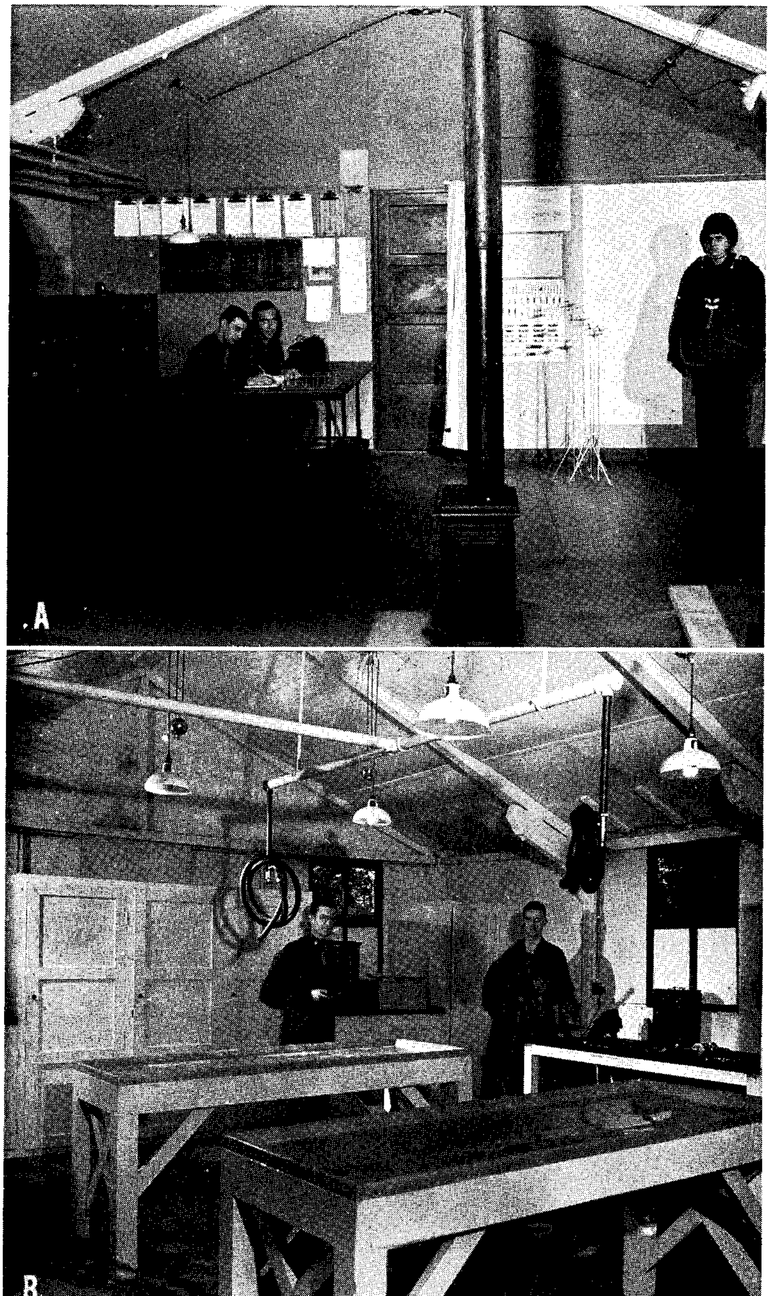


FIGURE 274.—Operational Research Section, Office of the Chief Surgeon, ETOUSA, located on the grounds of the Cambridge American Military Cemetery, Cambridge, England A. Workroom. B. Laboratory.

Cambridge American Military Cemetery (fig. 274). Examinations for the missile and injuries caused by the missile were made. No search was made in any part of the body where it was obvious a missile had not penetrated. The Graves Registration Service of the Quartermaster Corps at the Cambridge American Military Cemetery was very cooperative in notifying the Medical ORS when aircrew battle casualties were received for burial, so that the bodies could be brought immediately to the laboratory for examination.

Questionnaire forms, requesting such data as the circumstances of death, combat crew position, and altitude, were completed and forwarded by the group surgeons of the AAF stations from which the KIA casualties came. Of the 110 KIA casualties for the 3 months' period, 89 (81 percent) were examined at the Medical ORS. Of the 21 not examined, 7 were casualties who died in a hospital 1 to 6 days after being wounded.

Daily admission and disposition reports were received from the 12 hospitals serving the Eighth Air Force. From these, the entries of aircrew battle casualties were noted. There were 1,007 WIA battle casualties for the 3 months' period. Since ORS consisted of only one medical officer and one enlisted man during the first 2 months of the survey, it was impossible to visit and interrogate all battle casualties in hospitals before they were discharged. However, during the third month of the survey, interrogations were accomplished with the aid of additional enlisted men, and a total of 434 (43 percent) of the WIA were seen. X-ray records of the majority of the remaining WIA casualties were examined for missile size, number, and location, and for fractures. The hospital admission and disposition reports further served the purpose of determining the time spent in hospitals by WIA casualties and their redisposition to duty, to the Zone of Interior, or to a Detachment of Patients.

Further checking of the completeness of the casualty survey was accomplished by a medical officer of ORS visiting each of the 40 heavy bomber stations. The purpose of these visits was to verify the battle casualty status of aircrew members from a perusal of "Care of Flyer" reports of those patients missed in hospitals and to obtain information on battle casualties whose injuries were so slight as not to require hospitalization. The Care of Flyer reports also provided more accurate information on the final disposition of WIA casualties and on the time lost from flying status.

Missiles were identified from British and U.S.[2] ordnance publications and when necessary by consultation with a member of the Ordnance Office, USSTAF. Photographic records of missiles were made periodically by a photographer supplied by the Army Pictorial Service. It was not possible to have photographic equipment issued to the Medical ORS[3] for making photographic rec-

[2] USSTAF Ordnance Memorandum No. 5-2, 24 Mar. 1944, subject: German Ammunition.

[3] It is a sad reflection upon the imaginative foresight of the responsible officers to see this reluctance to furnish essential equipment. One of the most important aspects of any casualty survey is the photographic and X-ray record of the casualties. For the immediate purpose of the survey and to furnish a permanent record for future study and teaching, photographs of the external wounds and internal wound track with X-rays of the body regions involved are of paramount interest and value.—J. C. B.

ords of fatal wounds. The only such records available were those photographs taken at the AAF stations for the USSTAF surgeon's "Body Armor Reports." These photographs were borrowed and photostatic copies of them obtained. A 39-percent photographic coverage of KIA casualties from the 1st and 2d Divisions was achieved in this way. No photographs were available of casualties sustained by the 3d Division.

Aircraft Battle Damage

Group and squadron operations offices at each of the heavy bomber stations provided the identification number of each aircraft in which a KIA or a WIA battle casualty occurred, so that a report on the damage to the plane might be secured.

Permission was obtained from the Commanding General, Eighth Air Force, for the Medical ORS to borrow, for photostatic copying, the battle damage reports of heavy bomber aircraft in which casualties had occurred. These reports were prepared by the AAF station engineers on most damaged B–17 and B–24 aircraft and were forwarded to the Operational Research Section of the Eighth Air Force. The serial numbers of aircraft in which casualties occurred were obtained from every AAF station operations office and submitted to the Eighth Air Force Operational Research Section. Since only one copy of these battle damage reports was prepared, it was necessary to obtain, deliver for photostating, and return personally the reports at regular intervals. Battle damage reports pertaining to a total of 656 aircraft, in which there were 771 casualties, were obtained. This represents a 70-percent coverage of aircraft battle damage data associated with 70 percent of the casualties in the survey. Tables 177, 178, 179, and 180 give the number and types of the aircraft examined in this way by divisions, the cause of the damage, and the number of casualties per aircraft.

TABLE 177.—*Distribution of 541 casualties in 461 flak-damaged B–17 aircraft examined*

1st Division			3d Division		
Casualties in each aircraft	Aircraft examined	Total casualties	Casualties in each aircraft	Aircraft examined	Total casualties
1	221	221	1	176	176
2	33	66	2	18	36
3	4	12	3	6	18
4	2	8	4	1	4
	260	307		201	[1] 234

[1] Two of these casualties were hit with 20 mm. cannon shell fragments.

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TABLE 178.—*Distribution of 193 casualties in 172 flak-damaged B–24 aircraft examined*

3d Division			2d Division		
Casualties in each aircraft	Aircraft examined	Total casualties	Casualties in each aircraft	Aircraft examined	Total casualties
1	33	33	1	122	122
2	1	2	2	12	24
3	1	3	3	3	9
	35	38		137	155

TABLE 179.—*Distribution of 28 casualties in 19 examined B–17 aircraft damaged by missiles from fighter aircraft*

1st Division			3d Division		
Casualties in each aircraft	Aircraft examined	Total casualties	Casualties in each aircraft	Aircraft examined	Total casualties
1	10	10	1	3	3
2	2	4	2	1	2
3	3	9			
	15	23		4	5

TABLE 180.—*Distribution of 9 casualties in 4 examined B–24 aircraft damaged by missiles from fighter aircraft*

2d Division		
Casualties in each aircraft	Aircraft examined	Total casualties
1	1	1
2	1	2
3	2	6
	4	9

Flight Formations

The flight formations of heavy bombers over enemy territory on missions, during which there were battle casualties, were studied. Diagrammatic flight formations were obtained from the Operations Office, Operational Research Section, Eighth Air Force. A total of 288 complete group flight formation plans of Eighth Air Force heavy bombers was available. These formations were selected on the basis that in each one there was at least one

casualty in one aircraft. Thus, the relationship between casualties and flight formations for 539 battle casualties (48 percent of the total sample) was observed.

ANALYSIS OF BATTLE CASUALTIES

General

During the 3 months in which this survey of battle casualties returning to the United Kingdom was conducted, there were 1,117 battle casualties of whom 110 were killed and 1,007 wounded by enemy fire. Table 181 shows their distribution between the heavy bombardment groups. This represents a casualty rate of 0.172 percent (1.72 per 1,000) in terms of man-combat missions about which casualty data were available and 0.170 percent (1.70 per 1,000) of all man-combat missions. The ratio of MIA personnel to known battle casualties is approximately 6 to 1 (5.85 percent).

These figures may be compared with those given by the Surgeon, USSTAF, in his "Annual Report of Health" for 1943–44. For 1 year ending with the first month of the present survey, the battle casualty rate for the Eighth Air Force is reported as 0.201 percent (2.01 per 1,000) of man-combat missions credited. The MIA rate for the same period was 1.95 percent (19.5 per 1,000). The ratio of MIA personnel to known battle casualties was 9.7 percent or

TABLE 181.—*Distribution of 1,117 aircrew battle casualties of 1st, 2d, and 3d Divisions, by heavy bombardment group*

1st Division B-17's			2d Division B-24's			3d Division B-17's		
Group	Men wounded	Men killed	Group	Men wounded	Men killed	Group	Men wounded	Men killed
91st	20	2	44th	23	1	34th [1]	19	3
92d	49	2	93d	24	2	94th	56	5
303d	38	4	389th	17	4	95th	17	2
305th	44	7	392d	28	5	96th	32	2
306th	33	3	445th	18	------	100th	25	1
351st	29	1	446th	12	4	385th	20	1
379th	35	7	448th	23	1	388th	20	4
381st	28	4	453d	12	1	390th	33	7
384th	32	5	458th	13	1	447th	27	1
398th	27	------	466th	27	5	452d	34	4
401st	15	5	467th	15	3	486th [1]	25	2
457th	36	1	489th	36	3	487th [1]	9	2
			491st	19	3	490th [1]	9	2
			492d	16	------	493d [1]	12	------
	386	41		283	33		338	36

[1] Changed from B-24 aircraft to B-17 aircraft during July and August 1944.

nearly 10 to 1. Thus, the casualty rate and MIA rate for the 3 months which are the subject of this report are, respectively, 15.4 and 48.7 percent less than the corresponding figures for 1943–44.

In the present survey, the 1,117 battle casualties occurred in a total of 944 aircraft. Table 182 gives their frequency and distribution in the two types of heavy bombers. Approximately 72 percent of the casualties occurred with a distribution of one per aircraft. Multiple casualties per aircraft in the two types of heavy bombers did not differ significantly in their occurrence.

From the data in tables 176 and 182, it can be seen that the aircrew battle casualty rate is 2.10 per 1,000 man-combat missions in B–17's and 1.26 per 1,000 in B–24's. Thus, the risk of becoming a battle casualty was approximately two-thirds (67 percent) greater to B–17 personnel than it was to B–24 aircrew personnel. Since this conclusion is derived from an analysis of only those casualties who were brought back to the United Kingdom, it cannot be assumed that the real risk rates in the two types of bombers are as represented by the cited figures. If, for example, there was a higher casualty rate in missing B–24 personnel than in missing B–17 personnel, the figures could change significantly. However, with the available information, one must take account of the apparent difference which is very clearly significant. The reasons or causes for the difference merit further investigation. A fuller analysis of flak hits on aircraft in which casualties occurred appears in another chapter (p. 620).

TABLE 182.—*Frequency distribution of 1,117 battle casualties, by category, in 944 heavy bombers (B–17's and B–24's)*

Number of aircraft	Casualties per aircraft	Category		
		WIA	KIA	Total casualties
B–17:				
533	1	482	51	533
70	2	130	10	140
16	3	44	4	48
4	4	14	2	16
1	5	3	2	5
624		673	69	742
B–24:				
277	1	256	21	277
34	2	54	14	68
8	3	20	4	24
1	6	4	2	6
320		334	41	375
944		1, 007	110	1, 117

Causes of Casualties

Table 183 gives the causes of the wounds sustained by the 1,117 casualties. Approximately 86 percent of the casualties were hit by flak fragments. Less than 4 percent were hit by shells or shell fragments fired from enemy fighter planes. Practically all of the 7.8 percent of casualties hit by secondary missiles were the result of flak hits on the aircraft. Secondary missiles include fragments of Plexiglas; pieces of dural from the skin of, or objects in, the plane; bulletproof glass; brass fittings; and parts of electrical heating and radio equipment and .50 caliber machinegun ammunition.

Two unidentified missiles causing one KIA and one WIA casualty were found to be pieces of commercially pure zinc, the origin of which was not ascertained. There were three individuals who sustained injuries during more than one mission. Two were struck by flak fragments on two different missions and one was struck by Plexiglas on one mission and by flak on another. One of the two hit twice by flak was killed as a result of the second hit.

TABLE 183.—*Distribution of 1,117 aircrew battle casualties, by category and causative agent of wounds*

Causative agent	Category of casualty		Total casualty	
	WIA	KIA	Number	Percent
Flak fragments	865	98	963	86.2
Shells:				
20 mm	37	7	44	3.9
13 mm	3	1	4	.4
7.92 mm	2	----------	2	.2
Secondary missiles	84	3	87	7.8
Unknown	16	1	17	1.5
Total	1,007	110	1,117	100.0

Distribution of Casualties According to Combat Position

Table 184 shows the frequency with which aircrew personnel in different combat positions became missile casualties. In this and similar tables and figures, the positions of bombardier, togglier, and nose gunner, like those of the top turret gunner and engineer, are regarded as the same.

The high casualty rate for waist gunners was partially due to the fact that heavy bombers frequently carried two waist gunners. This practice was discontinued to a large extent, but accurate information as to the frequency with which aircrews included two waist gunners during the survey was not known.

The high casualty rates for navigators and bombardiers was to be expected from their positions in the nose of the aircraft. They lacked the protection provided by other personnel and portions of the ship's structure and by being

in the most forward compartments of the aircraft; they were exposed to the greatest density of flak. The leading edges of the wings and other parts of aircraft are known to receive a greater density of flak hits than trailing edges. The lowest incidence of casualties appears to occur in the ball turret gunner's position. This was partially due to the fact that only one of the two types of aircraft (B–17) carried a man in that combat position.

TABLE 184.—*Distribution of 1,117 battle casualties due to all missiles, by category and combat position*

Position	WIA casualties		KIA casualties		Total casualties		Case fatality rate (percent)
	Number	Percent	Number	Percent	Number	Percent	
Pilot	75	7. 4	8	7. 3	83	7. 4	9. 6
Copilot	68	6. 8	6	5. 5	74	6. 6	8. 1
Navigator	123	12. 2	13	11. 8	136	12. 2	9. 6
Bombardier	178	17. 7	18	16. 3	196	17. 6	9. 1
Radio operator	87	8. 6	8	7. 3	95	8. 5	8. 4
Waist gunner	212	21. 1	21	19. 0	233	20. 9	9. 0
Ball turret gunner	59	5. 9	7	6. 4	66	5. 9	10. 6
Top turret gunner	84	8. 3	10	9. 1	94	8. 4	10. 6
Tail gunner	121	12. 0	19	17. 3	140	12. 5	13. 6
Total	1, 007	100. 0	110	100. 0	1, 117	100. 0	9. 9

The Demarcation of Body Regions

The lack of a standardized method of demarcation of the regions of the body makes it impossible to compare accurately the distribution of wounds in any two or more collections of casualty data. Most of the available information pertains only to the wounded so that the true distribution of wounds or, more accurately, hits by bullets and fragments from high explosive shells has not been recorded. The military surgeons who cared for WIA casualties were the ones who recorded the locations of wounds. Their records have been the source of material from which casualty statistics have been compiled, and little information was obtained from their records concerning the difference between the wounds of entrance and of exit. Frequently, two or more wounds may have been produced by a single missile, but the surgeon was more concerned about the treatment of wounds than about the effectiveness of weapons or the development and use of body armor. Consequently, he usually failed to record the information which would enable those interested in body armor to compile accurate data pertaining to the regional distribution of hits and the type of causative agent.

In the Medical and Surgical History of the War of the Rebellion,[4] ref-

[4] The Medical and Surgical History of the War of the Rebellion. Surgical History. Washington: Government Printing Office, 1883, vol. II, pt. III, p. 691.

erence is made to the relative amounts of superficial area presented by the principal divisions of the human body from Longmore.[5] However, the relative percentages given for the different body regions are at variance with more recently determined measurements, particularly that for the head and neck region. Longmore's figure for the head region was 8.51 percent as compared with Burns and Zuckerman's figure of 12 percent.[6] In view of the fact that all complete casualty samples studied during World War II show wounds of the head and neck to be even in excess of 12 percent, it is likely that the measurement of Burns and Zuckerman is the more accurate one.

In this survey, the lines of demarcation between the body regions (fig. 275) were uniformly adhered to in accordance with those recorded by Burns and Zuckerman. The following is quoted from the British report:

> There are no agreed surface markings by which one region of the body can be definitely demarcated from another—e.g., the thorax from the neck. No absolute demarcation is possible because a line projected from the surface through the body would, in certain places, pass through two or more regions. For example a shot penetrating the body horizontally just below the ribs might easily pass both through the liver (an abdominal organ) and through the lower part of the lung (a thoracic organ). Again, shots in the buttock region could be regarded as wounds of the lower limb as well as wounds of the pelvis—if they penetrated deep enough. It was therefore necessary to define certain arbitrary lines of demarcation. The following were chosen as a fair compromise.
>
> *Head and Neck Region* (Symbol *H*)
>
> The demarcation of the head and neck region from the thorax presents difficulties in view of the fact that the domes of the pleurae extend an inch or so above the clavicles. A line passing transversely across the body an inch above the clavicles would, however, cut out a large part of the neck, and the part which lies below the cricoid cartilage. A compromise is suggested in a line which passes transversely one inch above the upper limit of the manubrium sterni. At the back the line chosen passes immediately below the spine of the seventh cervical vertebra (vertebra prominens). This point can easily be found as it lies immediately above the most prominent vertebra when the neck is slightly bent. In side view the lower limit of the neck is taken as a line which passes immediately above the line of the clavicle.
>
> *Chest Region* (Symbol *C*)
>
> The shoulders, both in front and behind, are most readily demarcated from the thorax and neck by a line which joins the upper limits of the anterior and posterior axillary folds with the point where the vertical neck joins the sloping shoulders.
>
> The demarcation of the thoracic cage from the abdomen presents difficulties. A compromise has been effected in a simple line which approximately demarcates the lower limit of the pleural cavities. In front this line is taken as passing from the lower end of the sternum obliquely downward and laterally to the eighth intercostal space. Where this line meets the anterior end of the eighth space a horizontal line is carried directly around the body, approximately across the spine of the first lumbar vertebra, to meet the anterior end of the eighth intercostal space on the opposite side.
>
> Consideration of the relations given in several works on surface anatomy suggests that this line, though not entirely accurate, is a fair compromise between the various statements that are made about the inferior margin of the pleural cavities.

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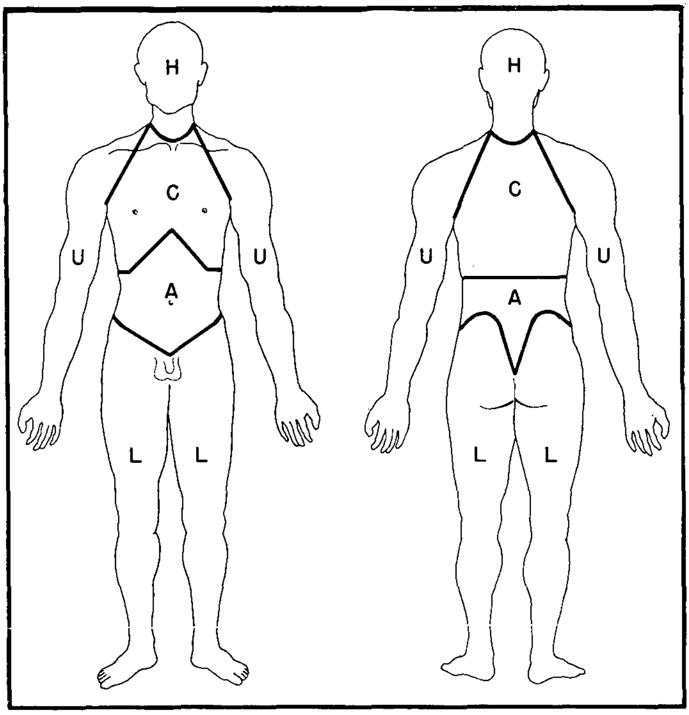
[5] Longmore, T.: Gunshot Injuries: Their History, Characteristics, Features, Complications, and General Treatment. London: Longmans, Green and Co., 1887, p. 595.

[6] Burns, B. D., and Zuckerman, S.: The Wounding Power of Small Bomb and Shell Fragments. R. C. No. 350 of the Research and Experiments Department of the Ministry of Home Security.



THE REGIONS OF THE BODY AS DEMARCATED ACCORDING TO THE DESCRIPTION IN THE TEXT

SYMBOL	REGION	PER CENT OF TOTAL BODY SURFACE AREA
H	HEAD AND NECK	12
C	CHEST	16
A	ABDOMEN	11
U	UPPER EXTREMITIES	22
L	LOWER EXTREMITIES	39

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FIGURE 275.—Outline form with demarcations of body regions.

It does not, however, clearly demarcate the thorax from the abdomen in so far as penetrating wounds of a lower part of the thoracic cage might very well enter the upper abdominal organs, and especially the liver. Furthermore, some shots through the subcostal angle might hit the posterior and inferior parts of the lungs.

Abdominal Region (Symbol *A*)

Lines chosen to demarcate the lower limits of the abdomen in front are those passing along the inguinal lines and meeting over the pubes. At the back the line curves from the region of the anterior superior spine, up laterally and then downward to just below the middle of the natal cleft. The latter point is approximately at the level of the ischial tuberosities.

Upper Extremity Region (Symbol *U*)

The lines of demarcation between the upper extremity region and head-and-neck and chest regions are as described under Chest Region.

Lower Extremity Region (Symbol *L*)

The lines of demarcation between the lower extremity and abdominal regions are as described under Abdominal Region. Any hit from the front or back above the level of these lines would penetrate into the lower part of the abdominal cavity. They therefore provide an adequate demarcation between the abdomen and lower limbs from these two aspects. Laterally, however, they are deficient as landmarks, since a shot could smash below their level through the hip region into the pelvis.

It should be noted again that the demarcations suggested above represent useful and practical compromises, and not absolute anatomical lines of limitation. Even were the latter definable, it is doubtful whether the results obtained would have been materially affected by their use, or indeed by any other set of practical lines of demarcation which might be suggested.

A great many difficulties were encountered in the analysis of extensive and multiple wounds, especially those observed in KIA casualties. The following criteria were adhered to closely:

1. Only wounds of entrance located in the region where missiles first struck the body were recorded as hits regardless of other regions traversed by the missile.

2. A wound or hit which appeared to be located on a line of demarcation between two regions was regarded as occurring in that region in which the missile track extended beyond the point of entry. For example, a wound at the junction of the chest and upper extremity would be a wound of the chest if the missile entered the chest or would be an upper extremity wound if it was confined to the shoulder or other part of the upper extremity.

3. Bruises and abrasions were disregarded, but all missile wounds in which the skin's surface continuity was interrupted were recorded.

4. Although it is possible for a soldier who has been killed by fragments from a bursting projectile to be struck after death by other shell fragments, an effort was made to disregard such secondary hits when it was obvious that they had occurred. For example, when there were wounds of entrance on opposite surfaces which could not have occurred from the burst of a single shell, only those hits thought to be inflicted primarily were recorded.

5. When there was doubt as to which was an entrance and which an exit wound, the choice depended arbitrarily on the missile track being directed above the horizontal plane, with the man standing erect.

6. In the case of extensive mutilating wounds of one or several regions of the body—obviously due either to very large fragments or direct hits by projectiles at the instant of or just before detonation—the location of such hits was regarded as being in the region located nearest the center of the area of mutilation.

7. When a mutilating wound involved an extremity and the area of mutilation was not continuous with the mutilation of the torso, an additional hit was recorded for the extremity, and its location was regarded as being at the most proximal level of traumatic amputation.

8. Wounds resulting from an injury in addition to wounds caused by missiles were disregarded unless they could have been the cause of death.

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Regional Distribution of Wounds Due to All Missiles

A distinction is made between the regional distribution and the regional frequency of wounds. In the former, a large number of wounds, considerably in excess of the number of casualties, may be distributed over the various regions of the bodies in a sample of casualties. Percentages in the tables that pertain to the regional distribution of wounds refer to the total number of wounds. In the case of regional frequency, one is concerned only with the frequency with which the various regions of the body are wounded regardless of the number of wounds in each body region. Percentages in the tables which pertain to the regional frequency of wounds refer to the number of casualties. From such tabulations, casualties who sustained wounds in more than one region of the body must either be excluded or an additional entry made for them; that is, for those hit or wounded in more than one region (Multiple, Symbol = *M*). Regional frequency tabulations in this survey include an additional entry for casualties wounded in more than one region of the body.

Table 185 shows the regional distribution of all wounds due to all missiles in 1,115 aircrew battle casualties. Two casualties, not included in table 185, were known to have been killed by flak before the crashlanding of their aircraft. They were badly burned, and the location of all their wounds could not be determined.

TABLE 185.—*Distribution of 1,553 wounds due to all missiles in 1,115 aircrew battle casualties, by category of casualty and by anatomic location (regional distribution) of wounds*

Anatomic location	Wounds in WIA casualties		Wounds in KIA casualties		Total wounds	
	Number	Percent	Number	Percent	Number	Percent
Head	258	19. 8	69	27. 1	327	21. 1
Chest	63	4. 9	37	14. 5	100	6. 4
Abdomen	28	2. 2	23	9. 0	51	3. 3
Extremities:						
Upper	382	29. 4	65	25. 5	447	28. 8
Lower	567	43. 7	61	23. 9	628	40. 4
Total	1, 298	100. 0	255	100. 0	1, 553	100. 0

On the basis of surface area presented by the different regions of the body, the wounds of the head and neck in all casualties (21.1 percent) are more frequent than would be expected. The projected surface area of this region is approximately 12 percent of the entire body (table 199). On the other hand, the wounds of the chest and abdomen, whose mean projected surface area is approximately 27 percent of the entire body, are far below the expected number.

This and other indications of the protective value of body armor will be discussed in the section on flak casualties (p. 570). In table 185 are included all wounds even though two or more may have been produced by a single missile following a straight path. The regional distribution of wounds or, more accurately, of hits caused by flak fragments only is given in table 200.

Regional Frequency of Wounds Due to All Missiles

Table 186 shows the regional frequency of wounds due to all missiles in 1,117 casualties. A comparison of the total percentages in tables 185 and 186 reveals the slight differences between regional distribution and regional frequency tabulations of wounds in the same complete sample of WIA and KIA casualties. If the regional frequency percentages had been calculated on the basis of casualties wounded in single regions only and if those wounded in multiple regions had been omitted from the sample, the differences in values by the two methods of presentation would have been even less significant.

TABLE 186.—*Distribution of 1,117 aircrew battle casualties, by category and by anatomic location (regional frequency) of wounds due to all missiles*

Anatomic location	WIA casualties		KIA casualties		Total casualties	
	Number	Percent	Number	Percent	Number	Percent
Head	182	18. 1	39	35. 5	221	19. 8
Chest	27	2. 7	11	10. 0	38	3. 4
Abdomen	10	1. 0	7	6. 4	17	1. 5
Extremities:						
Upper	246	24. 4	1	. 9	247	22. 1
Lower	419	41. 6	9	8. 2	428	38. 3
Multiple regions	123	12. 2	43	39. 0	166	14. 9
Total	1, 007	100. 0	110	100. 0	1, 117	100. 0

On the other hand, a comparison of the values from tables 185 and 186 demonstrates the relative differences in regional distribution and regional frequency tabulations of wounds that exist when samples of casualty data are broken down into WIA only and KIA only. The differences are only very slight in the case of the wounded but are very marked and of a different order entirely in the case of the killed. The reason for these differences is that the killed were much more frequently struck in multiple regions or rather that those casualties with multiple wounds were much more apt to die. Thus, head-and-neck and multiple regions were wounded in 74.5 percent of the KIA as compared with 30.3 percent in WIA casualties.

Fatality Rates

A survey of ground force casualties at Bougainville, S.I., from 15 February to 21 April 1944 (p. 281), was the first of its kind prepared by U.S. Army medical personnel that included an evaluation of wounds in both fatal and nonfatal American battle casualties. The overall case fatality rate among the ground force casualties in this sample was approximately twice as great as in the casualties of Eighth Air Force personnel. Probably, the main reason for this difference is the speed with which the air force casualties received adequate medical care. Table 187 compares the regional frequency of wounds and the case fatality rates in the Eighth Air Force in Europe and in the ground forces at Bougainville.

The marked difference in fatality rates in wounds of the head and neck (17.6 percent for Eighth Air Force casualties as compared with 37.5 percent at Bougainville) is at least partly due to the fact that a large number of the wounds of the head in Eighth Air Force casualties were mild lacerations due to Plexiglas fragments. Casualties due to flak fragments only in the Eighth Air Force and the casualties at Bougainville are compared in table 202.

TABLE 187.—*Case fatality rates in the 1,117 battle casualties of the Eighth Air Force and in the 1,788 casualties of the ground forces at Bougainville*

Anatomic location	Eighth Air Force		Ground forces at Bougainville	
	Number of casualties	Percent KIA	Number of casualties	Percent KIA
Head	221	17. 6	384	37. 5
Chest	38	28. 9	231	37. 6
Abdomen	17	41. 1	114	42. 1
Extremities:				
Upper	247	. 4	320	. 3
Lower	428	2. 1	407	3. 4
Multiple regions	166	25. 9	332	30. 4
Total	1, 117	9. 8	1, 788	22. 1

Single and Multiple Wounds

Table 188 gives the incidence of wounds occurring in one or more than one region of the body. The head and neck are regarded as one region. Wounds of both upper or both lower extremities are regarded as occurring in one region, whereas wounds in one or both upper and one or both lower extremities are regarded as occurring in two regions. Thus, 39.1 percent of the KIA casualties as compared with 12.2 percent of the WIA casualties sustained wounds in more than one region.

TABLE 188.—*Distribution of 1,117 battle casualties due to all missiles, by category and by number of regions wounded*

Regions wounded	WIA casualties		KIA casualties		Total casualties	
	Number	Percent	Number	Percent	Number	Percent
Number:						
1	884	87. 8	67	60. 9	951	85. 1
2	97	9. 6	29	26. 4	126	11. 3
3	25	2. 5	9	8. 2	34	3. 0
4	1	. 1	3	2. 7	4	. 4
5	--------	. 0	2	1. 8	2	. 2
Total	1, 007	100. 0	110	100. 0	1, 117	100. 0

Fractures and Amputations

The regional distribution of fractures due to all missiles is shown in table 189. In this analysis, fractures of both bones of the leg or forearm and of any number of bones of the shoulder, hip, wrist, or ankle joints and of the hand or foot or of the cranium are regarded as single fractures when produced at the same instant by one missile. When it was apparent that one missile had produced fractures in more than one region or, for example, when one missile had made an entrance and an exit wound of the same region, such as the chest or skull, and had fractured skeletal structures at both wounds, two fractures were counted. Fractures due to all missiles occurred in 31.8 percent of the casualties (26.3 percent of the wounded and 85.3 percent of the killed). In the study of fractures, the total 1,007 WIA casualties were available for study.

TABLE 189.—*Regional distribution of fracture wounds in 1,109 aircrew battle casualties due to all missiles*

Region	1,007 WIA casualties (265 or 26.3 percent with fractures)		102 KIA casualties [1] (87 or 85.3 percent with fractures)		Total casualties [2] (31.8 percent with fractures)	
	Number of fractures	Percent	Number of fractures	Percent	Number of fractures	Percent
Head	28	10. 0	48	45. 7	76	19. 8
Chest	12	4. 3	22	21. 0	34	8. 9
Abdomen	--------	. 0	1	1. 0	1	. 3
Extremities:						
Upper	111	39. 8	16	15. 2	127	33. 0
Lower	128	45. 9	18	17. 1	146	38. 0
Total	279	100. 0	105	100. 0	384	100. 0

[1] Of the total 110 KIA casualties, only 102 were available for study in regard to fracture occurrence.
[2] Of the total 1,117 WIA and KIA casualties, 1,109 were available for study in regard to fracture occurrence.

However, only 102 of the 110 KIA casualties were included in the fracture survey. This explains the variation in the figures for KIA casualties and wounds and total casualties as seen in tables 185, 189, and 190.

The relationship between wounds and fractures is given in table 190. Thus, for all wounds, the incidence of fractures was 24.8 percent. In the WIA casualties, 21.5 percent of the wounds were complicated by fractures, and in the KIA, 42.3 percent of the wounds were complicated by fractures. (Compare with table 189.)

Amputations are included as fractures in tables 189 and 190 and are shown separately in table 191. There was only one instance of a surgical amputation necessary following a soft-tissue wound. The injury was a through-and-through wound of the soft tissues anterior to the left femur, necessitating amputation of the left thigh. This amputation is not included in table 191.

TABLE 190.—*Relationship between wounds and fractures in 1,109 aircrew battle casualties due to all missiles, by anatomic location*

Anatomic location	WIA casualties			KIA casualties [1]			WIA and KIA casualties		
	Number of wounds	Number of fractures	Percent	Number of wounds	Number of fractures	Percent	Number of wounds	Number of fractures	Percent
Head	258	28	10. 9	67	48	71. 6	325	76	23. 4
Chest	63	12	19. 0	34	22	64. 7	97	34	35. 1
Abdomen	28	------	. 0	23	1	4. 3	51	1	. 2
Extremities:									
Upper	382	111	29. 1	64	16	25. 0	446	127	28. 5
Lower	567	128	22. 6	60	18	30. 0	627	146	23. 3
Total	1, 298	279	21. 5	248	105	42. 3	1, 546	384	24. 8

[1] Data are for 102 of the total 110 KIA casualties.

TABLE 191.—*Distribution of 34 traumatic amputations in 32 battle casualties, by anatomic location*

Anatomic location	Amputations		
	In WIA casualties	In KIA casualties	Total
	Number	*Number*	*Number*
Thigh	6	6	12
Leg	6	------------	6
Foot	5	1	6
Hand	6	------------	6
Arm	------------	4	4
Total	23	11	34

Of the WIA battle casualties, 23 (2.3 percent) sustained traumatic amputations; 20 of these amputations were due to flak. Of the remaining three, two were due to 20 mm. shells. The missile responsible for the amputation in the third case was not discovered. Two casualties had two amputations, one of both thighs and the other of one thigh and one arm. In the KIA group, all but one arm amputation, for which a 20 mm. cannon shell was responsible, were due to flak.

Return to Duty Status of Aircrew Battle Casualties

The severity of wounds sustained by aircrew battle casualties may be evaluated on the basis of time lost from flying status. For this analysis, casualties are regarded as KIA, permanently grounded, or grounded for periods of less than 24 hours, for 1 to 7 days, for 7 to 30 days, or for 30 to 90 days. The period of observation after injury was limited to 90 days. Thus, any casualty still in hospital or who had not returned to his organization after 90 days was regarded as permanently grounded. Tables 192 through 197 show the relative severity of wounds of different regions on the basis of time lost from flying status.

By regarding KIA casualties and those permanently grounded together, it is noted that 378 (33.8 percent) of the 1,117 battle casualties were permanently lost from flying status. Of the 739 casualties who returned to air-combat duty 99 (13.4 percent) lost less than a day; 256 (34.6 percent), less than a week; and

TABLE 192.—*Distribution of 221 aircrew battle casualties with wounds of the head and neck, due to all missiles, by disposition*

Disposition	Missile causing casualty						Total casualties	
	Flak		From fighter aircraft		Secondary or unknown			
	Number of casualties	Percent	Number of casualties	Percent	Number of casualties	Percent	Number	Percent
Returned to flying status after—								
0–1 day	11	8.3	------	0.0	27	32.1	38	17.2
1–7 days	21	15.9	3	60.0	36	42.9	60	27.1
7–30 days	32	24.2	------	.0	12	14.3	44	19.9
30–90 days	10	7.6	------	.0	------	------	10	4.6
Total	74	56.0	3	60.0	75	89.3	152	68.8
Permanently grounded	22	16.6	------	.0	8	9.5	30	13.6
Killed in action	36	27.4	2	40.0	1	1.2	39	17.6
Total	58	44.0	2	40.0	9	10.7	69	31.2
Grand total	132	100.0	5	100.0	84	100.0	221	100.0

563 (76.1 percent), less than a month from flying status. Wounds of the abdomen and of more than one body region accounted for the greatest relative loss of men from air-combat duty, the rates being 55.6 and 54.5 percent, respectively. Of those whose wounds were confined to the upper extremity, only 25.5 percent were permanently lost to air-combat duty.

TABLE 193.—*Distribution of 38 aircrew battle casualties with chest wounds due to flak fragments,*[1] *by disposition*

Disposition	Flak fragments	
	Number of casualties	Percent of casualties
Returned to flying status after—		
0–1 day	2	5.2
1–7 days	5	13.2
7–30 days	8	21.1
30–90 days	6	15.8
Total	21	55.3
Permanently grounded	6	15.8
Killed in action	11	28.9
Total	38	100.0

[1] During the survey period, flak fragments were responsible for all chest wounds.

TABLE 194.—*Distribution of 18 aircrew battle casualties with abdominal wounds due to all missiles, by disposition*

Disposition	Missile causing casualty						Total casualties	
	Flak		From fighter aircraft		Secondary or unknown			
	Number of casualties	Percent	Number of casualties	Percent	Number of casualties	Percent	Number	Percent
Returned to flying status after—								
0–1 day	------	0	------	0	------	0	------	0
1–7 days	4	26.7	------	0	------	0	4	22.2
7–30 days	3	20.0	------	0	------	0	3	16.7
30–90 days	1	6.6	------	0	------	0	1	5.5
Total	8	53.3	------	0	------	0	8	44.4
Permanently grounded	3	20.0	------	0	------	0	3	16.7
Killed in action	4	26.7	2	100.0	1	100.0	7	38.9
Total	15	100.0	2	100.0	1	100.0	18	100.0

TABLE 195.—*Distribution of 243 aircrew battle casualties with upper extremity wounds due to all missiles, by disposition*

Disposition	Missile causing casualty: Flak		Missile causing casualty: From fighter aircraft		Missile causing casualty: Secondary or unknown		Total casualties	
	Number of casualties	Percent	Number of casualties	Percent	Number of casualties	Percent	Number	Percent
Returned to flying status after—								
0–1 day	23	9.7	------	0	2	66.7	25	10.3
1–7 days	26	11.0	------	0	------	0	26	10.7
7–30 days	87	36.9	3	75.0	1	33.3	91	37.5
30–90 days	38	16.1	1	25.0	------	0	39	16.0
Total	174	73.7	4	100.0	3	100.0	181	74.5
Permanently grounded	61	25.9	------	0	------	0	61	25.1
Killed in action	1	.4	------	0	------	0	1	.4
Total	236	100.0	4	100.0	3	100.0	243	100.0

TABLE 196.—*Distribution of 421 aircrew battle casualties with lower extremity wounds due to all missiles, by disposition*

Disposition	Missile causing casualty: Flak		Missile causing casualty: From fighter aircraft		Missile causing casualty: Secondary or unknown		Total casualties	
	Number of casualties	Percent	Number of casualties	Percent	Number of casualties	Percent	Number	Percent
Returned to flying status after—								
0–1 day	30	7.6	1	5.5	------	0	31	7.4
1–7 days	47	11.8	2	11.1	------	0	49	11.6
7–30 days	105	26.5	8	44.5	1	16.7	114	27.1
30–90 days	99	24.9	2	11.1	2	33.3	103	24.5
Total	281	70.8	13	72.2	3	50.0	297	70.6
Permanently grounded	107	27.0	5	27.8	3	50.0	115	27.3
Killed in action	9	2.2	------	0	------	0	9	2.1
Total	397	100.0	18	100.0	6	100.0	421	100.0

TABLE 197.—*Distribution of 176 aircrew battle casualties with multiple wounds due to all missiles, by disposition*

Disposition	Missile causing casualty						Total casualties	
	Flak		From fighter aircraft		Secondary or unknown			
	Number of casualties	Percent	Number of casualties	Percent	Number of casualties	Percent	Number	Percent
Returned to flying status after—								
0–1 day	3	2.1	------	0	------	0	3	1.7
1–7 days	9	6.2	3	14.3	1	10.0	13	7.4
7–30 days	35	24.2	9	42.9	3	30.0	47	26.7
30–90 days	15	10.3	1	4.8	1	10.0	17	9.7
Total	62	42.8	13	62.0	5	50.0	80	45.5
Permanently grounded	46	31.7	4	19.0	3	30.0	53	30.1
Killed in action	37	25.5	4	19.0	2	20.0	43	24.4
Total	145	100.0	21	100.0	10	100.0	176	100.0

Blast Injury

Otoscopic examination of eardrums failed to reveal any case of blast injury in any of the 434 WIA battle casualties who were interrogated. The only instances of ruptured membrana tympani in the 89 KIA casualties examined were those that were torn as a result of basal skull fractures. It is known that rupture of the eardrums occurs at very much lower blast pressure than does lung damage and the absence of the former probably precludes the occurrence of any blast injury of the lungs.

CASUALTIES DUE TO FLAK

Distribution of Flak Casualties According to Combat Position

Because of the relatively large proportion (86.2 percent) of casualties due to flak, it was thought desirable to analyze them separately. Data pertaining to protection by body armor, altitude at which injuries were sustained, time interval between injury and adequate surgical treatment, time lost from flying status, sizes of fragments causing wounds, and the relative vulnerability of different parts of the body in different aircrew combat positions, will be discussed in this section. The frequency with which aircrew personnel in different combat positions became casualties due to flak is shown in table 198.

The fact that heavy bombers occasionally carried two waist gunners probably accounts for the highest flak casualty rate for that combat position

TABLE 198.—*Distribution of 963 casualties due to flak, by category and by combat position in heavy bombers*

Position	WIA casualties		KIA casualties		Total casualties		Case fatality rate (percent)
	Number	Percent	Number	Percent	Number	Percent	
Pilot	67	7.7	6	6.1	73	7.7	8.2
Copilot	58	6.7	6	6.1	64	6.6	9.4
Navigator	114	13.2	13	13.2	127	13.2	10.2
Bombardier	136	15.7	16	16.4	152	15.8	10.5
Radio operator	78	9.0	6	6.1	84	8.7	7.1
Waist gunner	191	22.2	18	18.5	209	21.6	8.6
Ball turret gunner	46	5.3	7	7.1	53	5.5	13.2
Top turret gunner	71	8.2	9	9.2	80	8.3	11.3
Tail gunner	104	12.0	17	17.3	121	12.6	14.0
Total	865	100.0	98	100.0	963	100.0	10.1

Also, the reasons for the relatively high casualty rates for bombardiers and navigators and the low casualty rate for ball turret gunners have been discussed previously.

Projected Body Surface Area

It was to be expected and it had been observed that high explosive shell fragments hit the body more at random than the "aimed" fire of bullets. Thus, it was to be expected that an analysis of wound distribution in a complete sample of WIA and KIA casualties due only to flak fragments might best reveal information pertaining to the relative degree of protection or lack of protection to the various body regions. In order to determine the mean projected area of the body and to make a correct estimate of the proportions of its different parts, it was necessary to weight observations according to the probable frequency of different positions of the body in actual operations. Unfortunately, there was no information on which to base an estimate of the correct weighting values. An arbitrary mean figure was obtained for the present study from the three views of the standing and kneeling figures and from the photograph taken from the front of the prone position (Burns and Zuckerman). By including the two other views of the prone position, the average value derived for the size of the human target may be slightly greater than the true mean projected service position. It is hardly likely that the error is as much as 5 percent. It should be noted that variations in the weighting factor would have a far greater influence on estimates of the mean projected area of the body and its parts than would alterations in the lines of regional demarcation discussed earlier. Seven men were measured, and, in spite of the differences in their size, the measurements showed a remarkable

similarity in the proportions of the mean projected area of each part of the body. Their heights and body weights were as follows:

Subject:	*Height (inches)*	*Body weight (pounds)*
1	72	144
2	72	182
3	72	146
4	70½	168
5	70	182
6	69	140
7	67	126

Table 199 gives the mean smoothed values for the actual projected surface areas in square feet and percent as determined from measurements of subjects 1, 2, 3, and 4. These percentage values may be regarded as the relative proportion of hits or wounds expected to be present in the various regions of the body in a random complete sample of casualties due only to high explosive shell fragments. Less than the expected number of wounds observed in any region would be a reflection of the protection of that region, while more than the expected number of wounds observed in any region would be due to a lack of protection to that region.

TABLE 199.—*Mean projected area of body*

Region	Square feet	Percent
Head and neck	0.50	12
Chest	.67	16
Abdomen	.46	11
Extremities:		
Upper	.92	22
Lower	1.65	39
Total	4.20	100

The Regional Distribution of Hits Due to Flak

Table 200 shows the location of 1,222 flak hits sustained by 961 battle casualties. Table 200 also shows the relationship between the wounds expected and the wounds observed for each of the body regions on the basis of the projected surface area of each of the regions. The lower incidence of wounds in the thoracic and abdominal regions protected by body armor is quite marked. Secondary wounds due to flak fragments traversing more than one region of the body were not counted here but were included in table 185, which lists all wounds due to all missiles. The rather noticeable decrease in the incidence of wounds of the head and neck in the flak casualties (15.6 percent) as compared with those due to all missiles (21.1 percent) was due to the frequency of Plexiglas wounds in the unprotected area of the head in bombardiers and navigators.

Surgeons' records frequently gave diagnoses of wounds of the face or head due to "Flak," when in reality interrogation of the casualties revealed that fragments of flak had penetrated Plexiglas covered areas of the noses of aircraft, dispersing myriads of Plexiglas fragments. The latter, however, seldom caused wounds of any part of the body other than the eyes, the circumorbital regions, and the neck. These wounds were usually mild and caused very little loss of time from flying status. The instances in which Plexiglas was found in other parts of the body usually occurred when fragments lodged in soft tissues after being driven ahead or along the track of the shell or other metallic fragments.

TABLE 200.—*Distribution of 1,222 flak hits on 961 aircrew battle casualties, by anatomic location*

Anatomic location	Hits in WIA casualties		Hits in KIA casualties		Total hits		Wounds expected (body surface area) (percent)
	Number	Percent	Number	Percent	Number	Percent	
Head	137	13. 1	54	30. 3	191	15. 6	12
Chest	51	4. 9	26	14. 6	77	6. 3	16
Abdomen	19	1. 8	10	5. 6	29	2. 4	11
Extremities:							
Upper	330	31. 6	52	29. 3	382	31. 3	22
Lower	507	48. 6	36	20. 2	543	44. 4	39
Total	1, 044	100. 0	178	100. 0	1, 222	100. 0	100

The Regional Frequency of Hits Due to Flak

Table 201 shows the regional frequency of flak hits sustained by 963 flak casualties. Again, the marked differences in the regional frequency of wounds in WIA as compared with KIA casualties are shown in this table.

TABLE 201.—*Distribution of 963 casualties, by category and by anatomic location (regional frequency) of flak hits*

Anatomic location	WIA casualties		KIA casualties		Total casualties	
	Number	Percent	Number	Percent	Number	Percent
Head	96	11. 1	36	36. 7	132	13. 8
Chest	27	3. 1	11	11. 2	38	3. 9
Abdomen	11	1. 2	4	4. 1	15	1. 6
Extremities:						
Upper	235	27. 2	1	1. 0	236	24. 5
Lower	388	44. 9	9	9. 2	397	41. 1
Multiple regions	108	12. 5	37	37. 8	145	15. 1
Total	865	100. 0	98	100. 0	963	100. 0

Fatality Rates

A comparison of fatality rates is shown in table 202. The first two columns compare the case fatality rates of wounds due to all missiles with those due to flak only in aircrew personnel. The larger percentage of fatal wounds of the head due to flak (27.4 percent as compared with 17.6 percent for all missiles) is explained by the relative mildness of Plexiglas wounds of the face which are included in the first column of the table. The lower fatality rate for flak wounds of the abdomen (26.7 percent as compared with 41.1 percent for all missiles) is explained by the severity of abdominal wounds due to missiles from enemy fighter aircraft. The third column shows the case fatality rates for ground force casualties at Bougainville. The higher case fatality rates which occurred in every region of the body in the series of Bougainville casualties must clearly be due in a large part to the fact that the wounds sustained by the ground forces concerned were more severe than the flak injuries received by the aircrews, which are the subject of the present report. It is known too that in jungle warfare as fought at Bougainville there was a preponderance of small arms or "aimed" fire, and it is known that a bullet is relatively much more lethal than a shell fragment. Another possible reason for the difference in case fatality rates in the Ground Forces and the Air Forces may be the greater speed with which air force casualties received surgical treatment. (See appendix H, page 843, for a detailed comparison of World War II missile casualty data.)

TABLE 202.—*Comparison of case fatality rates of wounds due to all missiles with those due to flak in Eighth Air Force and in the ground forces in Bougainville, by anatomic location of wounds*

Anatomic location	Eighth Air Force		Ground forces at Bougainville (all missiles)
	All missiles	Flak	
	Percent	*Percent*	*Percent*
Head	17.6	27.4	37.5
Chest	28.9	28.9	37.6
Abdomen	41.1	26.7	42.1
Extremities:			
Upper	.4	.4	.3
Lower	2.1	2.2	3.4
Multiple regions	25.9	25.5	30.4
Average	9.8	10.2	22.1

In general, the number of wounding missiles per casualty in the Air Forces was lower than in the ground force casualties. A possible explanation may

be the proximity of ground force casualties to bursts of exploding projectiles and to a greater degree of fragmentation of mortar and artillery shells as compared with antiaircraft shells.

Altitudes at Which Casualties Sustained Wounds

The altitude at which 441 (386 WIA and 55 KIA) casualties due to flak sustained wounds was known. Table 203 shows the manner in which the casualties were distributed between the two types of heavy bombers. Approximately 70 percent of casualties due to flak in B–17's were wounded at an altitude of 24,000 feet or above, whereas 92 percent in B–24's were wounded at 23,000 feet or below. This difference in altitude may in some way account for the difference in casualty rates in the two types of aircraft.

TABLE 203.—*Altitude of B–17 and B–24 aircraft at which 441 casualties due to flak sustained wounds*

Altitude in feet	Casualties in B-17's			Casualties in B-24's		
	WIA	KIA	Total	WIA	KIA	Total
Above 26,000	42	3	45	------	------	------
24,000–26,000	149	18	167	8	3	11
22,000–24,000	35	2	37	45	9	54
20,000–22,000	26	5	31	34	------	34
18,000–20,000	2	3	5	12	1	13
Below 18,000	12	9	21	21	2	23
Total	266	40	306	120	15	135

Time Interval Between Injury and Surgical Treatment

The time interval between injury and adequate surgical treatment in hospital was recorded for 375 WIA casualties due to flak. Table 204 shows the period of time which elapsed between injury and surgical treatment for casualties in the two types of aircraft. Approximately 90 percent of all WIA battle casualties were adequately treated in hospital within 4 hours after they were wounded.

Return to Flying Status

The relative severity of wounds due to all missiles, as judged by time lost from flying status, was shown in tables 192, 193, 194, 195, 196, and 197. Table 205 shows the time lost from flying status by the 963 casualties due to flak in the two types of aircraft. Thus, 64.3 percent of all casualties due to flak were returned to flying status within 3 months after being wounded.

TABLE 204.—*Distribution of 375 WIA casualties due to flak in B-17 and B-24 aircraft, by time interval between injury and surgical treatment*

Time interval	Number of casualties		
	In B-17's	In B-24's	Total
Hours:			
1	18	24	42
2	52	37	89
3	113	29	142
4	50	11	61
5	23	6	29
6	2	2	4
More than 6	6	2	8
Total	264	111	375

TABLE 205.—*Distribution of 634 and 329 casualties due to flak in B-17 and B-24 aircraft, respectively, by disposition*

Disposition	B-17		B-24	
	Number of casualties	Percent	Number of casualties	Percent
Returned to flying status after loss of—				
0–1 day	56	8. 8	13	4. 0
1–7 days	69	10. 9	43	13. 3
7–30 days	184	28. 9	86	26. 5
30–90 days	108	17. 0	61	18. 8
Total	417	65. 6	203	62. 6
Permanently grounded	157	24. 7	88	27. 2
Killed in action	60	9. 7	38	10. 2
Total	217	34. 4	126	37. 4
Grand Total	634	100. 0	329	100. 0

Relationship Between Flak Fragments and Disability

If the purpose of wounding enemy personnel is to cause military loss, then it is apparent that some means must be devised for evaluating that loss on the basis of severity of the wounds. Lamport [7] has stated: "If the tactical value of causing a casualty is considered as directly proportional to the days lost from full service, an incongruous result arises with a single casualty causing

[7] Lamport, H.: Missile Casualties Report No. 15, Office of Scientific Research and Development, Washington, D.C., September 1945.

100 days lost from duty being presumably equivalent in the military sense to putting each of ten men out of action for 10 days." Lamport has developed two hypotheses which may be used to demonstrate gradation of disability produced by wounds. For both of his methods, it was necessary to choose some period of disability, in days lost from active duty, that would correspond to the total military loss of a man. By the means described in his report, he arrived at the conclusion that a wound causing a man to lose 45 days amounts to a 100 percent military loss for that man and that a wound causing 6 days' loss amounts to a 50 percent military loss. Figure 276 is the curve representing Lamport's second hypothesis and shows the relationship between days lost from active duty and the percent tactical military loss.

The severity of wounds has been evaluated in terms of military losses ranging from 1 to 100 percent, and the values for these losses have been interpolated from a table which is contained in Lamport's report and reproduced here (table 206).

TABLE 206.—*Relationship between days lost from active duty by a casualty and the resulting military loss*

Days lost (T) (number)	Military loss (L)[1] (percent)	Grouping (percent)	Days lost (T) (number)	Military loss (L)[1] (percent)	Grouping (percent)
0	0	0	21	91	
1	11	1–10	22	92	
2	21	11–20	23	93	91–95
3	29½	21–30	24	94	
4	37	31–40	25	95	
5	44	41–50	26	95	
6	50	51–60	27	96	
7	56		28	96	
8	61		29	97	
9	65	61–70	30	97	
10	69		31	97	
11	72		32	98	
12	75	71–80	33	98	
13	78		34	98	
14	80		35	98	
15	83		36	98	96–100
16	84½		37	99	
17	86	81–90	38	99	
18	88		39	99. 0	
19	89		40	99. 1	
20	90		41	99. 2	
			42	99. 3	
			43	99. 4	
			44	99. 4	
			45	99. 45	

[1] Maximal loss (L) is 100 percent for $T=45$ days, when T=days lost from active duty. Method II (Annuity law) $L=100-100 \times 0.5066\frac{T}{6}$.

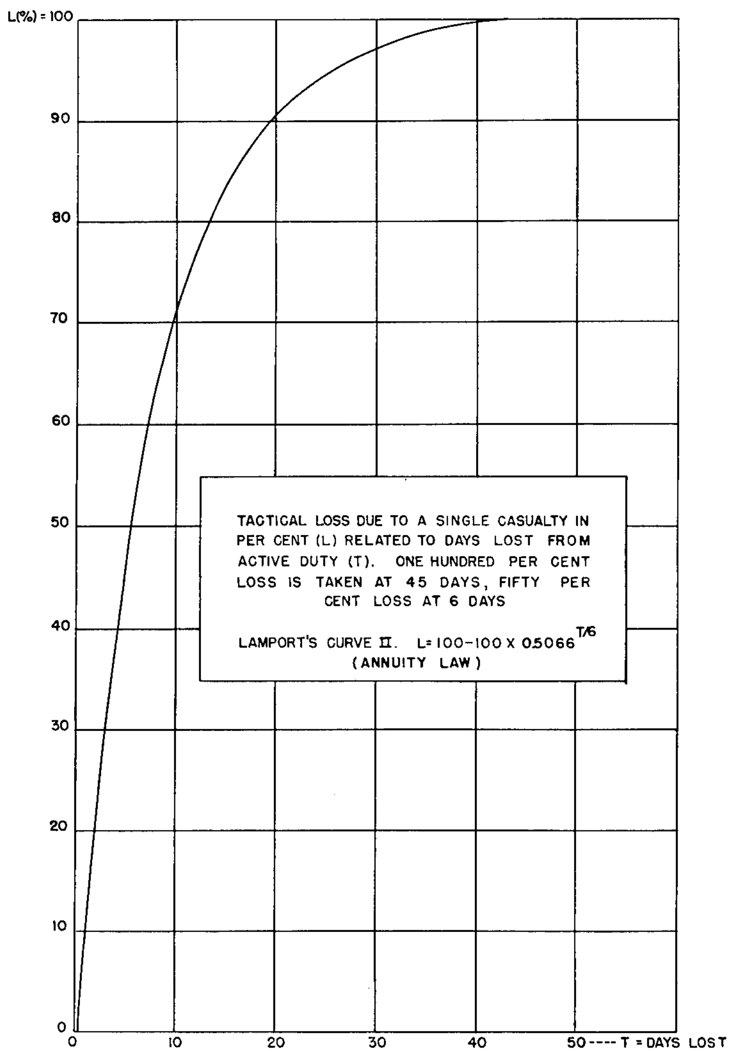

FIGURE 276.—Lamport's curve II, showing relationship between days lost from active duty and percent tactical military loss.

There were 376 instances where the complete flak fragments causing the wound were recovered. Added to these were casualties with through-and-through fatal wounds with either no fragment or only part of a fragment retained, fatal avulsions, amputations, and decapitations. For reasons to be given later, all of the latter fatalities were regarded as being due to fragments heavier than 20 grams. The total sample of data numbers 443 observations. These include the slightly and severely wounded, as well as those who were permanently disabled or killed. In calculating the correlation coefficient, the two variables taken into account were the days lost from flying status, inter-

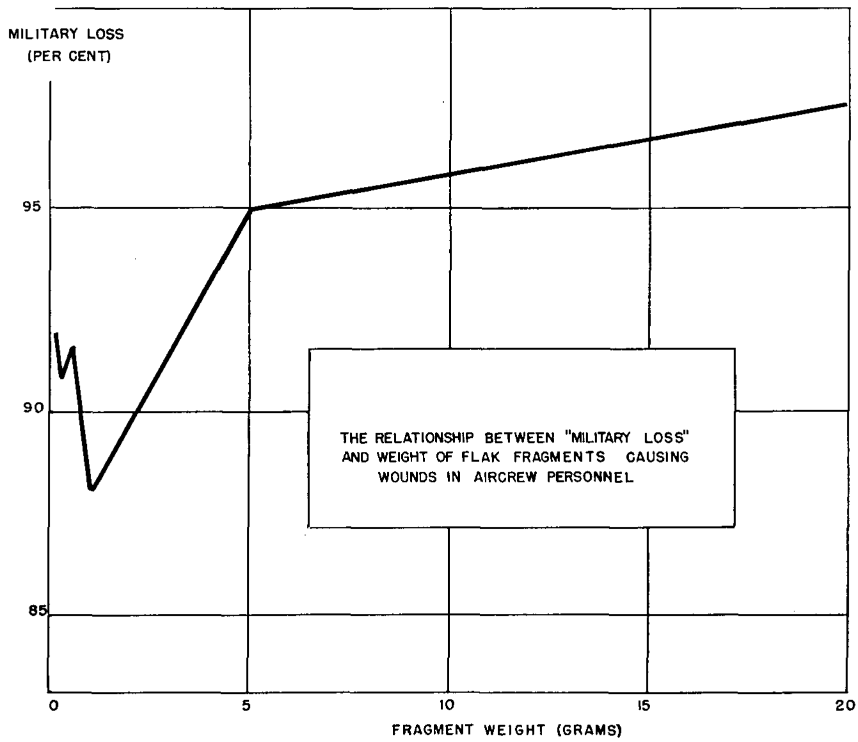

FIGURE 277.—Chart showing relationship between "military loss" and weight of flak fragments causing wounds in aircrew personnel.

polated from Lamport's table into percent military loss, and the size of the fragment in grams.

For the purpose of analysis, all casualties who were lost to flying status longer than 26 days, or who were permanently disabled or killed, were grouped together with those who lost from 27 to 45 days, or in terms of military loss, from 95 to 100 percent. The correlation coefficient for the two variables was found to be 0.288 ± 0.047. The test of significance (t) for the coefficient was found to be 6.13 (P=less than 0.01). The mean value for military loss per casualty was 90.0 percent (which corresponds to a loss of 21 days) and the mean fragment weight was 10.07 grams. A regression equation was calculated which was found to be:

$$x = 0.44y + 86.5$$

where x=percent military loss and y=fragment weight in grams. It may be observed, for example, from this equation that fragments weighing 1 gram generally may be expected to produce casualties, the average of which may be regarded as a military loss of 87 percent. From table 206, this is seen to

correspond to the loss of about 17 days. Figure 277 shows the relationship between "military loss" and fragment weight in the form of a curve plotted for the 443 observations upon which this report is based.

Despite all of the other variables that must be present, the observed correlation coefficient as calculated is statistically significant and may be regarded as real. It should be pointed out, as can be seen from the table of values for the two variables x and y, that fragments weighing more than 20 gm. produced the greatest number of permanently disabled or killed casualties. It may be assumed that fragments weighing more than 20 gm. were probably so damaging to personnel, as well as to aircraft, that they were responsible for casualties in aircraft that were shot down in enemy territory, and thus the casualties could not be included in the sample of data under survey. Otherwise, the number of observations in this group might have been greater still.

Correlation Between Wound Size and Fragment Size

It seems advisable to examine the relationship between the size of a wound and the size of the fragment causing it. It should be pointed out again that the lack of available information on the velocity of fragments prevents taking that important variable into consideration here. Accurate surface areas of wounds were not determined in most instances because of the irregular outline of the area margins. Instead, the surface area of a wound has been arbitrarily regarded as the product of two dimensions in centimeters. There were 75 instances in KIA flak casualties in which both the area of the wound of entrance and the fragment size were fairly accurately determined. In all of the observations, the flak fragments were completely retained along the wound track. The wounds ranged in size from 1 cm.^{2} to 50 cm.^{2}. The flak fragments ranged from 1 to 100 gm. in weight and from 1 to 9 cm. in their greatest dimension.

Correlation coefficients were calculated to show the relationship between (1) wound size and fragment weight and (2) wound size and greatest dimension of fragment. In the case of the former, the correlation coefficient was found to be 0.49 ± 0.12 (t=4.1; P=less than 0.01). This correlation is highly significant. The degree of correlation between the size of the wound and the greatest dimension of the flak fragment is even greater as shown by the correlation coefficient of 0.63 ± 0.12 (t=5.3; P=less than 0.01).

A further correlation coefficient was calculated; namely, that for the area of the wound against the product of the weight and maximum dimension of fragment. Although it was found to be significant, it was less so than either of the coefficients just given.

For this purpose, 36 fatal wounds due to flak fragments were available for study. Decapitations, avulsions, and amputations, obviously due to very large flak fragments, were deleted. Of the 36 fatal wounds, 6 retained part of the fragment along the wound track. The identity of the missile causing the wound in the other cases was confirmed by the knowledge that it was flak

that had damaged the aircraft in which the casualty occurred. The range of sizes in the fatal wounds in this group was from 1 $cm.^2$ to 108 $cm.^2$. The mean wound size was 20 $cm.^2$, for this sample. The difference between the means of the sizes of through-and-through wounds and the sizes of wounds with retained fragments is not statistically significant. However, if only those wounds due to retained fragments weighing less than 20 gm. (54 observations) are compared with through-and-through fatal wounds, the difference in their respective mean sizes is significant—the difference being 13.80 $cm.^2$ (standard error ± 5.14). Therefore, through-and-through fatal wounds in this series of observations may be regarded generally as being caused by fragments weighing more than 20 grams.

Sizes of Fragments Causing Wounds

The sizes of flak fragments responsible for wounds were determined by weighing those recovered from the dead and estimating the weights of others from their X-ray silhouettes. In the case of the latter, the fragments were estimated in grams from their linear dimensions. A large series of X-rays of fragments of known weight were available as a standard. A total of 505 flak fragments seen in X-ray films or recovered from 438 (361 WIA and 77 KIA) casualties were available for study.

The KIA casualties from whom flak fragments were available were only those examined in the Medical ORS laboratory during the 6 months' period, June through November 1944. There were 164 bodies examined from the Eighth Air Force and Ninth Air Force and Troop Carrier Command. Of the total, 144 (87.8 percent) were flak casualties. The 81 fragments causing fatal wounds in 77 casualties represent the recovery of 54.0 percent of flak fragments causing fatal wounds. Although some flak fragments were recovered from the other KIA casualties, they were not included in this analysis because there was evidence that the fragments found were only portions of the fragments causing the fatal wounds. In several instances, fragments smaller than expected were found along a missile track having both entrance and exit wounds.

In general, it may be assumed that those fragments which were completely recovered were of lower velocity and of smaller size than those which caused fatal wounds in the remaining 67 (46.5 percent) KIA casualties, from whom none or only partial fragments were recovered. In instances where more than one fragment was found in a fatal wound with one point of entrance, it was assumed that refragmentation of the primary fragment had occurred. In nearly all such cases, the refragmented fragments could be fitted together. The weight credited for such multiple fragments was the total weight of the pieces. Fragments which caused secondary wounds in KIA casualties are included in the group of fragments causing nonfatal wounds. Table 207 shows the weight distribution of flak fragments according to nonfatal and fatal wounds.

In three KIA casualties, there were two fragments, both of which caused fatal wounds. Four fragments are credited with having caused fatal wounds,

TABLE 207.—*Weight distribution of 505 flak fragments recovered from nonfatal and fatal wounds in 438 casualties*

Type of wound	Number of casualties	Number and weight of fragments						Total fragments
		0–50	50–250	¼–1	1–5	5–20	>20	
		Mg.	*Mg.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Number*
Nonfatal	361	56	64	46	100	100	58	424
Fatal	77	------	------	------	6	43	32	81
Total	438	56	64	46	106	143	90	505

although they were recovered from the extremities. Two of these were recovered from the knee joint of one casualty and weighed 15.29 and 6.10 gm., respectively. The other two were removed from the thighs of two casualties and weighed 12.04 and 31.74 gm., respectively. In each of these cases, the actual cause of death was attributed to hemorrhage, shock, and anoxia.

A series of flak fragments of varying sizes are seen in figure 278.

Sizes of Fragments Causing Fracture Wounds

Thirty flak fragments were recovered which had caused thirty fracture wounds of the skull. Twenty-three (77 percent) of these produced fatal wounds. The 30 fragments were distributed according to weight as shown in table 208. Again, it should be stated that many fatal skull fracture wounds were observed from which no fragments were recovered. Thus, it may be concluded that flak fragments weighing more than 5 gm. are much more likely to cause fatal penetrating wounds of the skull than fragments weighing less than 5 grams.

TABLE 208.—*Weight distribution of 30 flak fragments recovered from nonfatal and fatal fracture wounds of the skull*

Type of wound	Number and weight of fragments			Total fragments
	1–5	5–20	>20	
	Gm.	*Gm.*	*Gm.*	*Number*
Nonfatal	3	3	1	7
Fatal	1	16	6	23
Total	4	19	7	30

Fifty-six flak fragments were recovered which had caused fracture wounds of the extremities. The distribution of these fracture wounds is shown in table 209. Only complete fractures of the bones or joints listed, in which the mis-

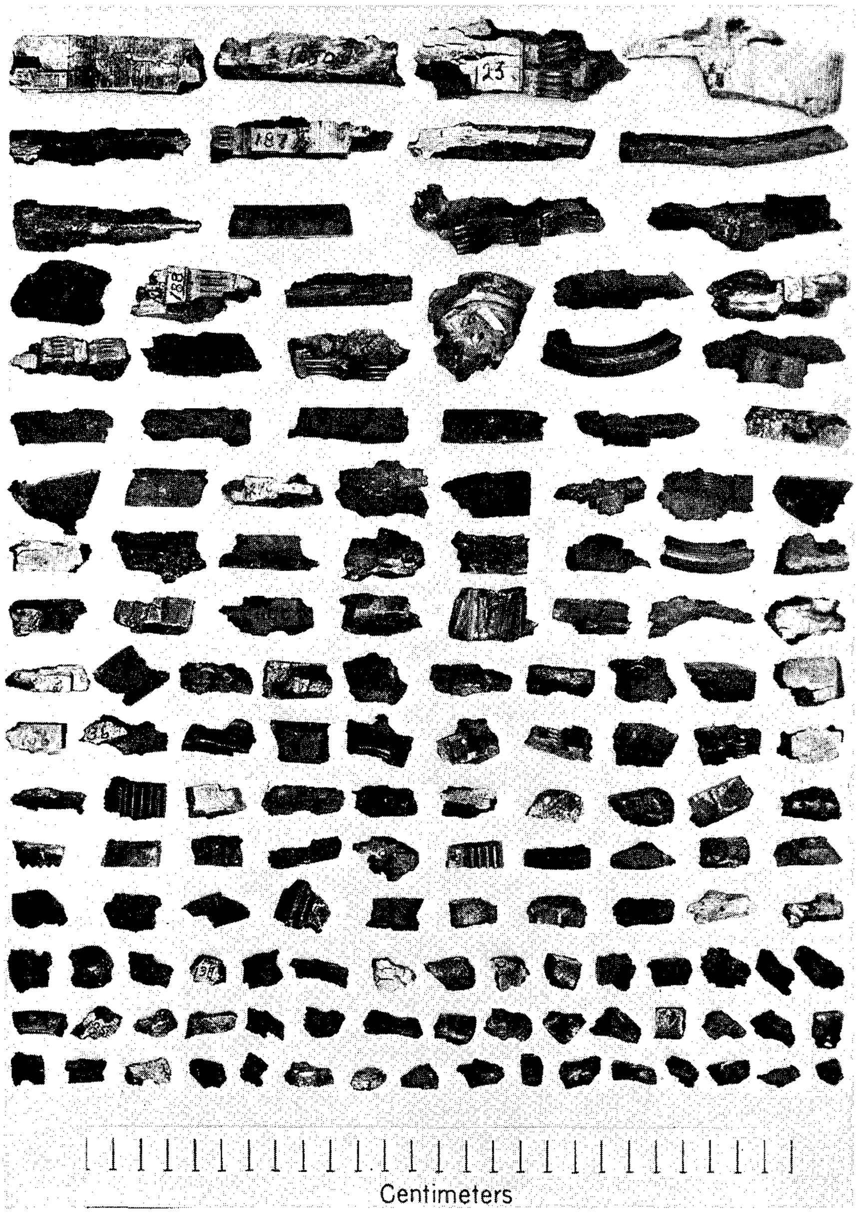

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FIGURE 278.—Primary missiles (flak). Each of these fragments caused a fatal heavy bomber aircrew casualty. They range in weight from 1 to 106 gm. Some of them are broken-off retained portions of larger fragments that produced fatal through-and-through wounds. It was observed that no flak fragment weighing less than 1 gm. had been found to produce a fatal wound and that probably no fragment weighing less than 20 gm. was capable of producing a through-and-through fatal wound.

siles were retained at the site of the fracture, were included. Thus again, in general, only fragments weighing more than 5 gm. produced fatal fracture wounds of the extremities.

TABLE 209.—*Weight distribution of 56 flak fragments recovered from fracture wounds of the extremities*

Fracture wound of—	Weight and number of fragments					Total fragments
	50–250	¼–1	1–5	5–20	>20	
	Mg.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Number*
Humerus				5	1	6
Elbow		1	1	2	1	5
Radius and/or ulna			1	2	1	4
Wrist		1		1		2
Femur			2	4	4	10
Knee				6	1	7
Tibia and/or fibula	1	2	2	6	4	15
Ankle			2	2	3	7
Total	1	4	8	[1] 28	[2] 15	[1] 56

[1] Includes 6 fatal fracture wounds; 1 of the humerus, 2 of the femur, 2 of the knee, and 1 of the tibia and/or fibula.
[2] Includes 1 fatal fracture wound of the femur.

Flak, Mortar, and Artillery Shell Fragments

In a report by the Bombing Survey Unit on American ground force casualties sustained in the Cassino area (p. 541) are some data on the sizes of mortar and artillery shell fragments causing nonfatal wounds. The sizes of fragments causing fatal wounds were not determined. Table 210 compares the sizes and distribution of 424 flak fragments which caused nonfatal wounds in 361 aircrew casualties with 157 mortar and artillery shell fragments which caused wounds in 27 ground force casualties.

TABLE 210.—*Comparison of flak fragments in nonfatal wounds in 361 aircrew casualties with mortar and artillery shell fragments in 27 ground force casualties in the Cassino area*

Flak fragments in 361 aircrew casualties			Mortar and shell fragments in 27 ground force casualties		
Weight	Number	Percent of total fragments	Weight	Number	Percent of total fragments
Mg.			*Mg.*		
0–50	56	13. 2	0–50	77	49. 0
50–250	64	15. 1	50–250	29	18. 5
Gm.			*Gm.*		
¼–1	46	10. 8	¼–1	33	21. 0
1–5	100	23. 6	1–5	18	11. 5
5–20	100	23. 6	5–20		
>20	58	13. 7	>20		

The increased average number of fragments per casualty in the ground forces (5.8 percent as compared with 1.2 percent per aircrew casualty) may be partially explained by the breakup of fragments after hitting. The lower carbon content of the steel from which mortar and artillery shells are made would account for the finer breakup and the greater irregularity in the shape of their fragments. The preponderance of wounds in ground force casualties associated with fragments smaller than 1 gm. in weight (88.5 percent as compared with 39.1 percent for aircrew casualties) attests to the greater vulnerability of ground force troops and to the greater protection of aircrew personnel against small low-velocity fragments. The casualty risk rate for troops from mortar and artillery fire in the Cassino area was estimated to be approximately 27 percent. This was the estimated casualty rate for two infantry regiments exposed to enemy mortar and artillery fire during 7 days of combat. Even with all MIA aircrew personnel included as battle casualties, the casualty rate for the Eighth Air Force for 3 months was only 1.2 percent.

The Effect of Body Armor on the Distribution of Flak Wounds

It has been impossible to collect accurate data to show the incidence of personnel hit but uninjured by flak in the regions of the body protected by armor. Records in the Office of the Surgeon, USSTAF, showed only 15 such instances for the 3 months' period of this survey. An evaluation of the protection afforded by armor may be obtained from a study of the quantitative relationship between flak hits and projected body surface areas. This relationship is shown in table 211. The values in the table are based on the 1,222 flak hits observed in the 961 casualties referred to in table 200 and may be regarded as indices of vulnerability. The mean areas of the different regions of the body used in the calculations are the same as those referred to in table 199 and are shown in table 211 as "Hits expected." The application of mean projected surface areas as measured to a man usually seated in a heavy bomber is a purely arbitrary one. The presence of combat equipment and the structure of the aircraft in addition to the wearing of body armor probably influenced the regional distribution of flak hits materially. A purely random distribution of hits on unprotected individuals would cause all the indices in the table to be 1.00. The effective protection to the chest and abdomen is apparent as indicated by indices of 0.39 and 0.22 for these regions, respectively. An index of 1.42 for the upper extremities reveals this region to be most vulnerable to hits in aircrew personnel. It should be pointed out that the relatively high vulnerability index of 1.30 for the head-and-neck region is due largely to the relatively greater vulnerability of the neck rather than of the head itself. When one compares the vulnerability of different body regions as demonstrated in table 211 with the regional distribution of hits (table 200), the point that is demonstrated in the former is the relatively high vulnerability of the head and neck and upper extremities in proportion to the surface area projected by these regions.

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TABLE 211.—*Relative vulnerability of different body regions as compared with the 1,222 flak hits observed on body surface area of 961 casualties*

Body region	Body surface area or hits expected	961 WIA and KIA aircrew casualties (body armor worn)	
		Hits observed	Index [1]
	Percent	*Percent*	
Head	12. 0	15. 6	1. 30
Chest	16. 0	6. 3	. 39
Abdomen	11. 0	2. 4	. 22
Extremities:			
Upper	22. 0	31. 3	1. 42
Lower	39. 0	44. 4	1. 14
Total	100. 0	100. 0	

[1] Index = $\frac{\text{Percent of hits observed}}{\text{Percent of hits expected}}$

Table 212 is a breakdown of the regional distribution of flak hits given in table 200 according to combat position. The values are expressed as percentages of total hits received in each combat position.

Table 213 shows the quantitative relationship between flak hits and body surface areas in terms of vulnerability indices for each of the combat positions in U.S. heavy bomber aircraft. Here again, it may be said that a purely random distribution of hits on unprotected individuals would cause all the values in the table to be 1.00. Thus, for example, the ball turret gunner appears to have the greatest protection from flak hits of the abdomen. The copilot appears to have the least chest protection, or at least he sustains the greatest number of chest hits. However, it is clearly apparent that throughout the

TABLE 212.—*Regional distribution of flak hits according to combat position*

[Values expressed as percentages of total hits received in each position]

Combat position	Head	Chest	Abdomen	Upper extremity	Lower extremity
Pilot	20. 2	5. 3	2. 1	28. 7	43. 7
Copilot	15. 2	9. 4	1. 1	30. 6	43. 7
Navigator	18. 9	9. 1	3. 2	32. 0	36. 8
Bombardier	19. 7	5. 7	1. 5	37. 9	35. 2
Radio operator	9. 7	2. 9	1. 9	29. 1	56. 4
Waist gunner	14. 9	6. 0	2. 6	30. 6	45. 9
Ball turret gunner	9. 2	4. 6	0	27. 7	58. 5
Top turret gunner	20. 2	5. 7	2. 9	18. 3	52. 9
Tail gunner	9. 5	7. 0	3. 8	36. 9	42. 8
Average	15. 6	6. 3	2. 4	31. 3	44. 4

different combat positions the number of flak hits of the chest and abdomen in proportion to the areas these regions present is relatively low. It is also apparent that one of the vital regions of the body, that is, the head and neck, of a man in any combat position is relatively poorly protected from flak. The head and neck are most vulnerable in the pilot's and top turret gunner's positions.

TABLE 213.—*Relative vulnerability (index of vulnerability) of body regions in different combat positions*

Combat position	Head	Chest	Abdomen	Upper extremity	Lower extremity
Pilot	1. 68	0. 33	0. 19	1. 31	1. 12
Copilot	1. 27	. 59	. 11	1. 39	1. 12
Navigator	1. 58	. 57	. 30	1. 46	. 94
Bombardier	1. 64	. 36	. 14	1. 72	. 90
Radio operator	. 81	. 18	. 18	1. 32	1. 44
Waist gunner	1. 24	. 37	. 24	1. 39	1. 18
Ball turret gunner	. 77	. 29	0	1. 26	1. 50
Top turret gunner	1. 68	. 36	. 26	. 83	1. 36
Tail gunner	. 80	. 44	. 35	1. 68	1. 09

The choice of the measurements for projected surface areas was purely arbitrary and since the areas were measured for a man not in an aircraft are likely to be quite different for a man in his aircrew combat position. Perhaps a more accurate estimate of the projected surface areas of body regions for aircrew personnel and the effectiveness of body armor could be obtained from an analysis of flak wound distribution in samples of armored and unarmored aircrew personnel. The available material for such an analysis consisted of 104 of the flak casualties in the present survey (88 WIA and 16 KIA) who were known not to be wearing body armor. In addition to these, a perusal of Eighth Air Force records before the introduction of body armor revealed 307 known flak casualties (294 WIA and 13 KIA) which were sustained during the period August 1942 to December 1943.

Table 214 shows the distribution of flak wounds in unarmored and armored aircrew personnel. The figures in column 3 for armored individuals are those given in table 200 for all casualties due to flak, less those known to have been sustained in unarmored personnel.

Flak wounds of the chest and abdomen before the use of body armor accounted for 13.3 percent of the casualties as compared with 8.2 percent since the use of body armor. Chi-square test of the significance of the differences between these figures gives the value $\chi^2=9.70$ ($n=1$, P less than 0.005). From the numbers available, this difference is very highly significant.

A number of unarmored KIA casualties were omitted from columns 1 and 2 of table 214 because the identity of the missiles causing the fatal wounds could not be ascertained from the old records. Could these have been in-

TABLE 214.—*Regional distribution of flak wounds in unarmored and armored aircrew personnel*

Region	Wounds in unarmored casualties [1]		Wounds in armored casualties [2]	
	Number	Percent	Number	Percent
Head	92	16. 1	173	16. 1
Chest	56	9. 8	59	5. 5
Abdomen	20	3. 5	29	2. 7
Extremities:				
Upper	151	26. 4	349	32. 5
Lower	252	44. 2	465	43. 2
Total	571	100. 0	1, 075	100. 0

[1] 382 WIA; 29 KIA.
[2] 777 WIA; 80 KIA.

cluded, the incidence of wounds of the head, chest, and abdomen undoubtedly would have been greater and the apparent beneficial effect of body armor marked. Protective steel helmets were generally worn by aircrew personnel both before and since the introduction of body armor and, as might be expected, the incidence of flak wounds of the head remained unchanged.

An analysis was made of the incidence and case fatality rates of flak injuries of the head sustained by men wearing and not wearing steel helmets. Information was obtained from 458 aircrew casualties, 369 of whom wore helmets and 89 of whom did not wear helmets (table 215). Only those regions of the head normally protected by a steel helmet were considered in this analysis.

TABLE 215.—*Distribution of 458 casualties with cranial injuries due to flak, by protected or unprotected helmet area*

Helmet area	Number of casualties	Total wounds		Fatal wounds	
		Number	Percent	Number	Percent fatality
Protected	369	33	8. 9	19	58
Unprotected	89	13	14. 6	10	77
Total	458	46	10. 1	29	63

It would appear that both the incidence and case fatality rate of injuries of the head due to flak were decreased by the wearing of the steel helmet. However, the sample of data was not sufficient to give statistical significance to the differences between either the incidence or the case fatality rate for cranial wounds of protected and unprotected individuals.

CASUALTIES DUE TO SECONDARY MISSILES

The Distribution of Casualties Due to Secondary Missiles

A total of 104 aircrew battle casualties (100 WIA and 4 KIA) were due to secondary or unknown missiles. This represents 9.3 percent of the total of 1,117 casualties in the 3 months' survey. As stated previously, secondary missiles include fragments of Plexiglas, pieces of dural from the skin of or objects in the plane, bulletproof glass, brass fittings, parts of electrical heating and radio equipment, and .50 caliber machinegun ammunition (figs. 279, 280, 281, and 282). In this analysis, however, secondary missiles left in wounds along

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FIGURE 279.—Secondary missiles (dural). The most common of secondary missiles in aircrew casualties are the aluminum alloy fragments from the skin and other parts of aircraft known as dural. Only the top left fragment, the tip of the throttle of a B–17, produced a fatal wound by transecting a man's trachea and lodging in his neck alongside his vertebral column. The other pieces were found along the fatal wound tracks caused by primary missiles.

the path of enemy missiles were not included. Only those missiles which alone were responsible for wounds, secondary to hits elsewhere by flak or fire from enemy aircraft, were included. Table 216 shows the distribution of battle casualties due to secondary and unknown missiles.

Plexiglas Wounds

All of the WIA casualties due only to Plexiglas sustained injuries from fragments of Plexiglas set in motion by flak. In one instance, a fragment of a 20 mm. cannon shell, in addition to a fracture wound of the right arm, caused

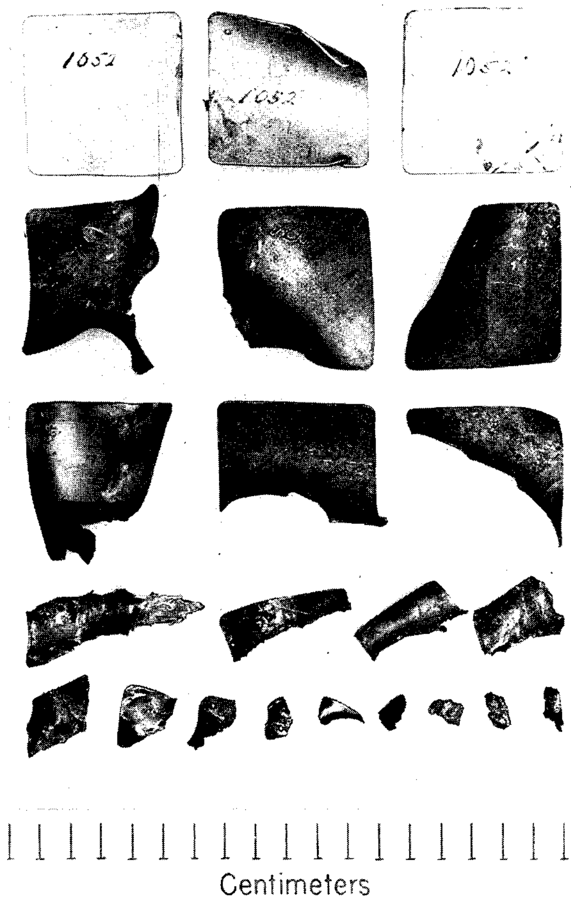

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FIGURE 280.—Secondary missiles (body armor). The second most common of secondary missiles found in the tracks of fatal wounds in aircrew personnel are plates and fragments of body armor and helmet. These are most readily recognized by their uniform thickness of approximately 1 millimeter and by the fact that they are nonmagnetic though obviously of greater density than fragments of dural.

a secondary Plexiglas wound of the face. In 73 of the casualties, the wounds produced by the fragments of Plexiglas were the only ones sustained, and all of these occurred in the unprotected area of the face and neck with the exception of one, which was in the forearm. Two others sustained two wounds from Plexiglas fragments, one each of the head and forearm. Out of the total of 88 Plexiglas wounds in 76 individuals, there were only 3 that occurred on protected parts of the body; that is, parts of the body protected by as little as the sleeves of the man's uniform. These three wounds occurred on the forearms of three individuals. Figure 283 shows diagrammatically the loca-

tion of the 85 (97 percent) Plexiglas wounds that occurred on the unprotected part of the body. Plexiglas wounds were sustained by men in all combat positions. However, bombardiers, navigators, and top turret gunners accounted for 68 percent of them.

TABLE 216.—*Distribution of 104 aircrew battle casualties, by category and by causative agent (secondary missile)*

Causative agent	WIA casualties	KIA casualties	Total casualties
Plexiglas	76		76
Dural	4	1	5
Bulletproof glass	3		3
Motor bearing		1	1
Zinc fragment	1	1	2
.50 caliber machinegun ammunition		1	1
Unknown	16		16
Total	100	4	104

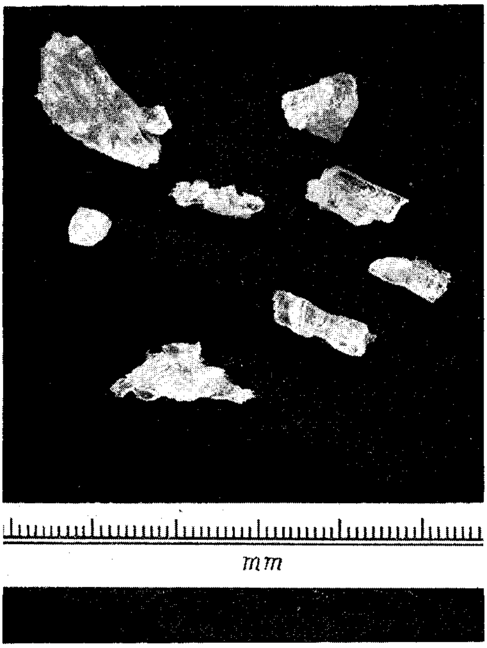

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FIGURE 281.—Secondary missiles (Plexiglas). The third most common of secondary missiles causing wounds in aircrew personnel are fragments of Plexiglas. These fragments do not produce fatal wounds and never penetrate deeply into tissue except when driven in by a heavier primary missile. Plexiglas fragments produce only slight superficial wounds and lacerations by themselves.

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FIGURE 282.—Secondary missiles (miscellaneous). These consist of a bearing from an aircraft's engine, parts of electrical apparatus, clothing, personal equipment, oxygen line, rubber, zipper, and "dog tag" chain. With the exception of the bearing which by itself produced a fatal head wound, all of these were found in aircrew personnel along the fatal wound tracks caused by primary missiles.

Return to Flying Status of Casualties Caused by Secondary Missiles

Table 217 shows the relative severity of wounds due to Plexiglas and other secondary and unknown missiles as judged by the time lost from flying status.

There is a striking difference in the severity of wounds due to Plexiglas fragments as compared with wounds due to flak and other missiles. Thus,

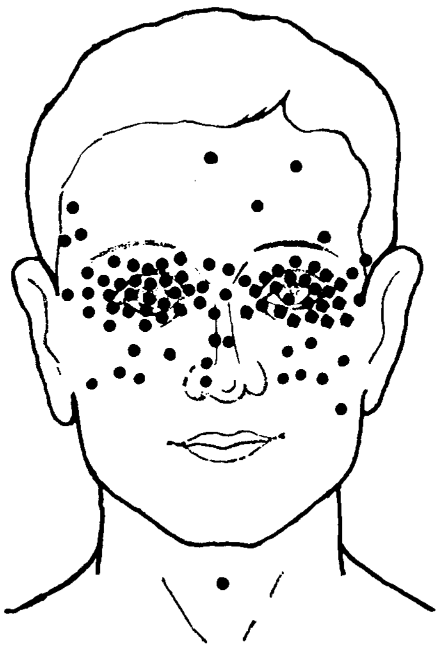

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FIGURE 283.—Location of 85 wounds due to Plexiglas fragments in 75 WIA battle casualties.

TABLE 217.—*Distribution of 104 aircrew battle casualties due to Plexiglas fragments and other secondary or unknown missiles, by disposition*

Disposition	Plexiglas fragments		Other secondary or unknown missiles	
	Number	Percent	Number	Percent
Returned to flying status after loss of—				
0–1 day	24	32	5	18
1–7 days	31	41	5	18
7–30 days	14	18	4	14
30–90 days	1	1	2	7
Total	70	92	16	57
Permanently grounded	6	8	8	29
Killed in action	----------	----------	4	14
Total	6	8	12	43
Grand total	76	100	28	100

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none were killed and only 8 percent of men wounded by fragments of Plexiglas were permanently grounded, whereas 43 percent of men wounded by flak or other missiles were permanently grounded or killed.

CASUALTIES DUE TO MISSILES FROM ENEMY FIGHTER AIRCRAFT

Causes of Casualties

In the present survey, 50 battle casualties (4.5 percent) were known to be due to missiles fired from enemy aircraft. Their distribution according to missile (figs. 284, 285, and 286) and type of casualty is shown in table 218. Cannon shells (20 mm.) accounted for 88 percent of the casualties.

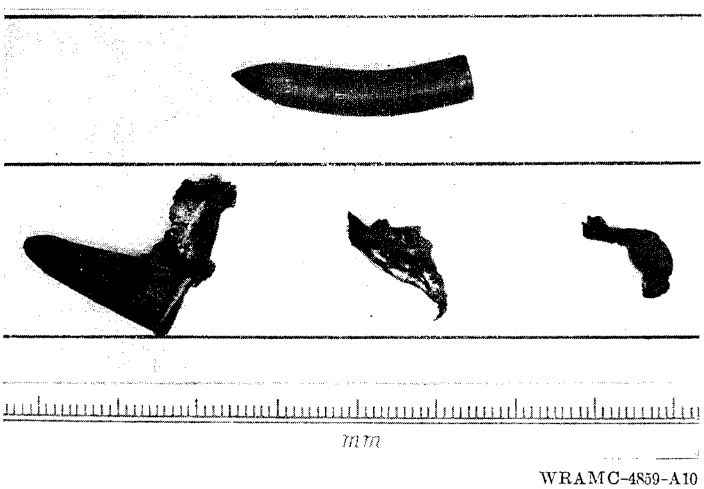

FIGURE 284.—Primary missiles (7.92 mm.). The top specimen is the steel core of an armor-piercing 7.92 mm. Mauser bullet. The fragments in the bottom group are from the jacket of the same type of bullet.

TABLE 218.—*Distribution of 50 aircrew battle casualties, by category and by missile fired from enemy aircraft*

Missile	Category		Total casualties	
	WIA	KIA	Number	Percent
	Number	*Number*		
20 mm	37	7	44	88
13 mm	3	1	4	8
7.92 mm	2		2	4
Total	42	8	50	100

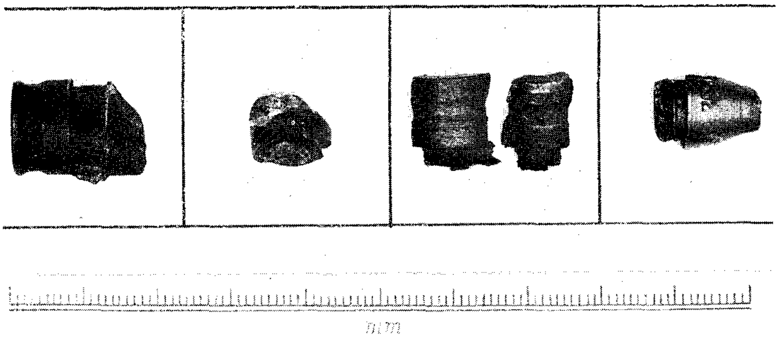

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FIGURE 285.—Primary missiles (13 mm.). Each fragment or group of fragments was found in fatal wounds of aircrew personnel. The two on the left are from armor-piercing and the two on the right are from high explosive shells. The 13 mm. cannon shell was the smallest caliber missile in which a high explosive charge was used.

Distribution of Casualties According to Combat Position

Table 219 shows the distribution of the 50 casualties according to combat position. Although the number of casualties is quite small, it may be noted that, as in the case of casualties due to flak, the waist gunner appears to be the man most vulnerable to fighter attack. This is at least partially accounted for by the fact that two waist gunners were frequently carried in heavy bombers. The tail gunner is probably most vulnerable to fighter attack. This is in agreement with the findings of the Eighth Air Force Operational Research Section that the greatest directional density of hits on heavy bombers by enemy cannon and machineguns is from dead astern.

TABLE 219.—*Distribution of 50 aircrew casualties due to missiles fired from fighter aircraft, by category and combat position*

Combat position	Category	
	WIA	KIA
	Number	*Number*
Pilot	2	1
Copilot	4	
Navigator	2	
Bombardier		
Radio operator	7	2
Waist gunner	11	2
Ball turret gunner	5	
Top turret gunner	3	1
Tail gunner	8	2
Total	42	8

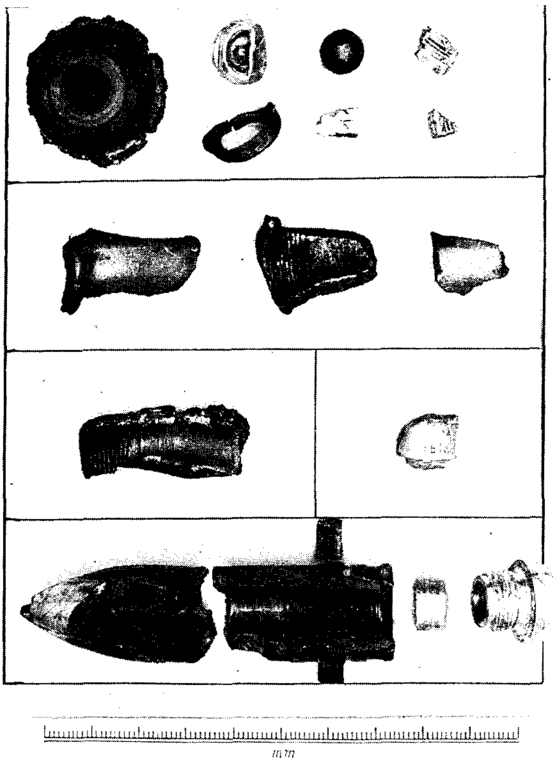

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FIGURE 286.—Primary missiles (20 mm.). Each fragment or group of fragments caused, and was found in, a fatal wound of aircrew personnel. All except the bottom group were from high explosive shells. The bottom specimen has been reconstructed from the retained fragments found in a through-and-through fatal wound produced by a 20 mm. armor-piercing incendiary cannon shell. The shell broke up in the wound as the result of its having perforated a flak suit worn by the casualty. Plates and fragments of the man's body armor were also found in the wound.

It is apparent from the distribution of casualties in table 219 that bombardiers and navigators were least likely to be casualties from enemy fighter attack. This might be expected on the basis that enemy fighters are least likely to attack the nose of an aircraft from the front. The low incidence of casualties due to missiles from fighter aircraft as compared with the high incidence due to flak for the bombardier and navigator positions substantiates the finding that these positions are susceptible to an increased density of flak hits because of their leading and exposed positions with respect to the rest of the aircraft.

Regional Distribution of Wounds Due to Missiles From Enemy Fighter Aircraft

Table 220 shows the distribution of 83 wounds in 50 casualties struck by missiles fired from enemy fighter aircraft. The wound distribution in this

group of casualties differs from that in flak and other missile casualties in that there is an increase in the occurrence of wounds of the vital regions of the body. Less than 25 percent of flak wounds occurred in the head and trunk regions as compared with an incidence of 35 percent for head and trunk wounds due to missiles from enemy fighter aircraft.

TABLE 220.—*Distribution of 83 wounds in 50 aircrew battle casualties due to missiles fired from fighter aircraft, by category of casualty and anatomic location (regional frequency) of wounds*

Anatomic location	WIA casualties		KIA casualties		Total casualties	
	Number of wounds	Percent	Number of wounds	Percent	Number of wounds	Percent
Head	13	19	6	38	19	23
Chest	3	5	3	19	6	7
Abdomen	2	3	2	12	4	5
Extremities:						
Upper	20	30	3	19	23	28
Lower	29	43	2	12	31	37
Total	67	100	16	100	83	100

Single and Multiple Wounds Due to Missiles From Enemy Fighter Aircraft

Table 221 shows the frequency with which one and more than one region of the body was wounded by missiles fired from enemy fighter aircraft in the 50 casualties. The increased multiplicity and severity of wounds in this group of casualties may be compared with those sustained by casualties due to all missiles (table 186) and flak casualties (table 201). In both of the latter, only 15

TABLE 221.—*Distribution of 50 aircrew battle casualties due to missiles fired from fighter aircraft, by category and number of regions wounded*

Regions wounded	WIA casualties		KIA casualties		Total casualties	
	Number	Percent	Number	Percent	Number	Percent
Number:						
1	25	59. 5	4	50. 0	29	58. 0
2	10	23. 8	1	12. 5	11	22. 0
3	6	14. 3	2	25. 0	8	16. 0
4	1	2. 4	1	12. 5	2	4. 0
Total	42	100. 0	8	100. 0	50	100. 0

percent were wounded in more than one region as compared with 42 percent of casualties wounded in more than one region due to missiles from enemy fighter aircraft.

Altitude at Which Casualties Sustained Wounds

The altitude at which 27 of the 50 (54 percent) casualties sustained wounds was known. Table 222 shows distribution of the casualties and the type of aircraft in which they were wounded.

There are no significant variations in the distribution of B–17 casualties according to altitude. Of 5 B–24 casualties, 4 were wounded or killed below 22,000 feet. This is in agreement with the observations made pertaining to the altitude at which casualties due to flak were sustained; namely, that B–24 aircraft usually operated at a lower altitude than B–17 aircraft.

The difference in the occurrence of casualties in the two types of aircraft is marked (76 percent in B–17's and 24 percent in B–24's). However, the frequency with which B–17's and B–24's were attacked by enemy fighter aircraft is not known. Thus, the relationship between fighter damage to aircraft and the occurrence of casualties was not determined, and an evaluation of the significance of the difference in the occurrence of casualties in the two types of aircraft could not be made.

TABLE 222.—*Distribution of 50 aircrew battle casualties (38 in B–17's; 12 in B–24's) due to missiles fired from enemy fighter aircraft, by altitude*

Altitude in feet	Casualties in B–17's			Casualties in B–24's		
	WIA	KIA	Total	WIA	KIA	Total
Above 26,000 feet	1		1			
24,001 to 26,000 feet	7	1	8			
22,001 to 24,000 feet	1	2	3	1		1
20,001 to 22,000 feet	2		2		1	1
18,001 to 20,000 feet	7		7	1	1	2
Below 18,000 feet	1		1	1		1
Unknown	14	2	16	6	1	7
Total	33	5	38	9	3	12

KIA CASUALTIES—JUNE THROUGH NOVEMBER 1944

During the 6 months from June through November 1944, the bodies of 164 KIA battle casualties from the Eighth Air Force and Ninth Air Force and Troop Carrier Command were examined in the laboratory of the Medical ORS.

During the last 2½ months of the survey period, the Office of the Surgeon, USSTAF, provided additional facilities and personnel to aid the ORS in the examinations.[8]

Causes of the Fatalities

The missiles causing fatal wounds in 164 casualties are shown in table 223. The proportion of fatalities due to flak (87.8 percent) is approximately the same as the incidence of all aircrew battle casualties due to flak (86.2 percent).

TABLE 223.—*Distribution of 164 KIA aircrew casualties, by missile*

Missile	Casualties	
	Number	Percent
Flak	144	87. 8
From fighter aircraft	[1] 10	6. 1
Secondary	4	2. 4
Unknown	6	3. 7
Total	164	100. 0

[1] Of these, 8 casualties were due to 20 mm. missiles and 1 each to 13 mm. and 7.92 mm. missiles.

Distribution of KIA Casualties According to Combat Position

Table 224 shows the distribution of 164 KIA casualties according to combat position. The positions of KIA casualties of the Ninth Air Force and Troop Carrier Command not accounted for in heavy bombers are included under "Position unknown." The occurrence of fatal casualties and thus the case fatality rates for casualties in any combat position do not appear to differ significantly except as previously noted in table 184.

Regional Distribution of Wounds

Table 225 shows the regional distribution of all entrance wounds due to all missiles in this larger sample of 164 KIA battle casualties. The distribution of wounds in the different body regions is not appreciably different from that of the smaller sample of 110 KIA casualties described previously in table 185.

Regional Frequency of Wounds

Table 226 shows the regional frequency of wounds in the larger sample of KIA casualties.

[8] From the examination of the casualties referred to in this section, complete data pertaining to the morbid anatomy, histopathology, arteriography, and X-ray appearance of fatal wounds were compiled. Lack of space, however, precludes inclusion of this information on the 164 casualties examined. Another report on these casualties is also contained in AAF Memorandum Report, TSEAL-3697-7B, 1945, by J. B. Hickam, Aero Medical Laboratory, Wright Field, Ohio.

TABLE 224.—*Distribution of 164 KIA aircrew casualties, by combat position*

Position	Casualties	
	Number	Percent
Pilot	9	5. 5
Copilot	10	6. 1
Navigator	20	12. 2
Bombardier	22	13. 4
Radio operator	17	10. 4
Waist gunner	32	19. 5
Ball turret gunner	7	4. 2
Top turret gunner	10	6. 1
Tail gunner	28	17. 1
Unknown	9	5. 5
Total	164	100. 0

TABLE 225.—*Distribution of 451 wounds in 164 KIA aircrew casualties due to all missiles by anatomic location*

Anatomic location	Wounds	
	Number	Percent
Head	105	23. 3
Thorax	58	12. 9
Abdomen	32	7. 1
Extremities:		
Upper	145	32. 1
Lower	111	24. 6
Total	451	100. 0

TABLE 226.—*Distribution of 164 KIA casualties due to all missiles, by anatomic location (regional frequency) of wounds*

Anatomic location	Casualties	
	Number	Percent
Head	50	30. 5
Chest	16	9. 8
Abdomen	3	1. 8
Extremities:		
Upper	----------	0
Lower	11	6. 7
Multiple regions	84	51. 2
Total	164	100. 0

Comparison of tables 225 and 226 reveals again that the differences in the regional incidence of wounds by the two methods of tabulation, that is, wounds versus casualties, are quite marked. These differences are characteristic of all samples of KIA casualties and as stated before are due primarily to the high incidence of multiple wounds in the dead.

Single and Multiple Wounds

Table 227 shows the incidence of single and multiple wounds in KIA casualties. The KIA casualties were struck in more than one region four times as often as the WIA casualties. In the 3 months' survey of all casualties as discussed earlier in this chapter, multiple wounds were more than three times as frequent in KIA as in WIA casualties (39.0 percent in the KIA as compared with 12.2 percent in the WIA). The incidence of multiple regions wounded in this larger sample of KIA casualties (includes 89 of the 110 KIA from the smaller sample) was 50.0 percent. The increased number of multiple wounds in the larger sample was most marked in about half of the sample; that is, those casualties sustained during September, October, and November 1944. Such a significant increase, which would be even more marked if the incidence of multiple wounds for the first 3 months were to be compared separately with that for the second 3 months, may be regarded as being due to the increased use of higher burst velocity shells by the enemy.

TABLE 227.—*Distribution of 164 KIA aircrew battle casualties, by single and multiple regions wounded*

Number of regions wounded	Number of casualties	Percent of casualties
1	82	50. 0
2	49	29. 9
3	22	13. 4
4	7	4. 3
5	4	2. 4
Total	164	100. 0

Incidence of Fractures in KIA Casualties

Table 228 shows the distribution of 265 fractures according to body regions. Of the fractures in KIA casualties, 72.9 percent were associated with wounds of the vital areas of the head and trunk regions as compared with 14.3 percent in WIA casualties (table 189).

The 91 percent incidence of fractures in KIA casualties (in 149 of the 164) reported here as compared with 85.3 percent reported for the smaller sample (87 of the 102) may be explained by the increased multiplicity of wounds in the larger sample.

TABLE 228.—*Distribution of 265 fractures in 149 KIA aircrew battle casualties due to all missiles, by anatomic location*

Anatomic location	Number of fractures	Percent of fractures
Head	102	38.5
Chest	86	32.5
Abdomen	5	1.9
Extremities:		
Upper	34	12.8
Lower	38	14.3
Total	265	100.0

Causes of Death in KIA Battle Casualties Due to All Missiles

Table 229 shows the regional distribution of wounds which were the causes of death in 164 KIA casualties. There were 11 casualties in which either of 2 hits could have been fatal and 2 casualties in which any 1 of 3 hits could have been fatal. However, for this tabulation, the following criteria were followed in order to determine the primary fatal wound:

1. Only the severest one of multiple fatal wounds was regarded as the cause of death in any one casualty.
2. When the severity of a head and a chest or abdominal wound appeared to be the same, the cause of death was arbitrarily attributed to the head wound.
3. When the severity of a chest and an abdominal wound appeared to be the same, the cause of death was attributed to the chest wound.
4. Decapitations were regarded as causes of death due to wounds in the head-and-neck region in cases where the head was missing as well as in other cases where a head wound was very extensive and associated with complete evulsion of the brain.

TABLE 229.—*Distribution of 164 aircrew battle casualties due to all missiles, by anatomic location in which the primary fatal wound occurred*

Anatomic location	Number of casualties	Percent of casualties
Head	74	45.1
Chest	63	38.4
Abdomen	12	7.4
Extremities:		
Upper	------------	0
Lower	15	9.1
Total	164	100.0

TABLE 230.—*Distribution of 164 KIA aircrew battle casualties due to all missiles, by anatomic location and type of fatal wound*

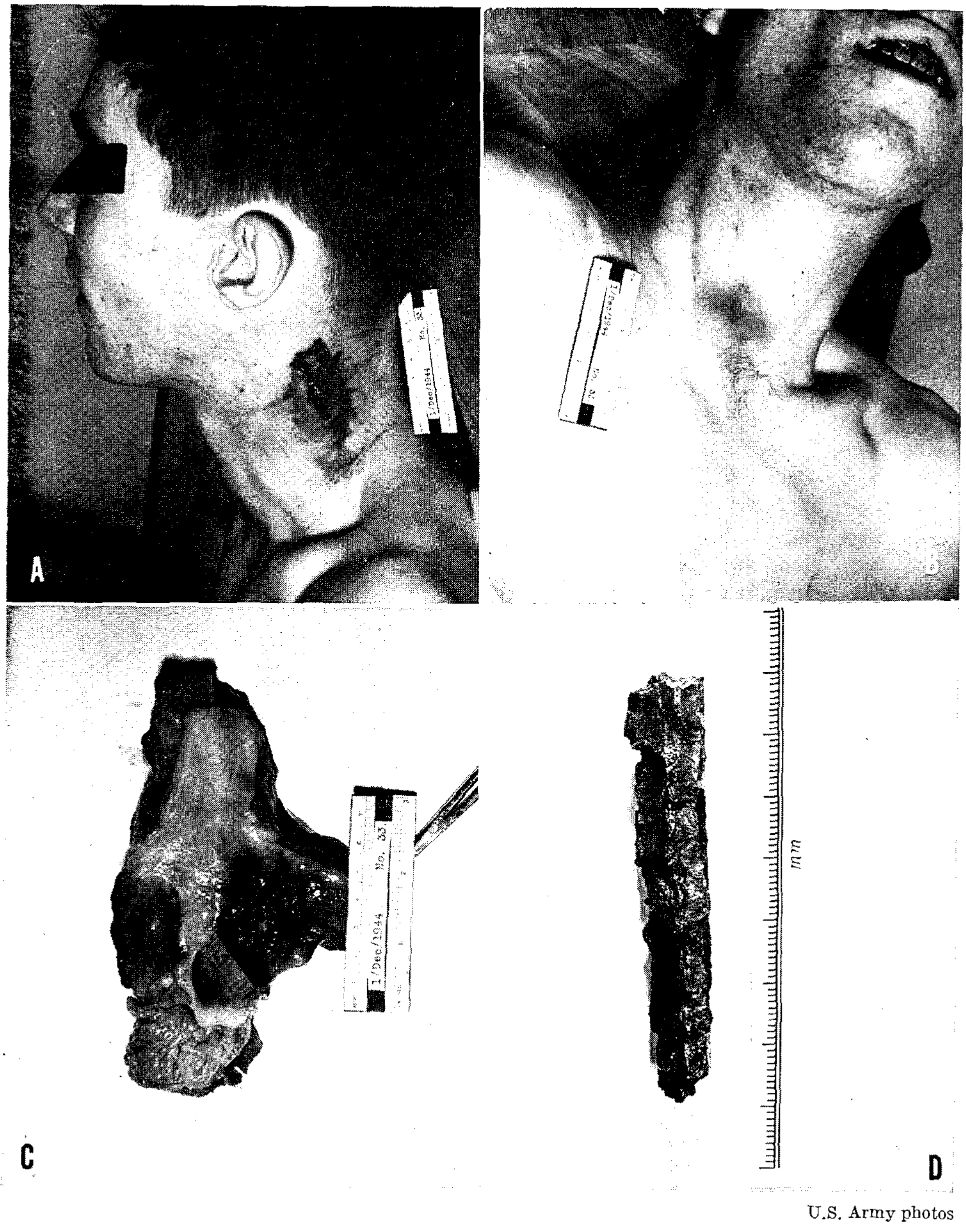
Anatomic location and type of wound	Number of casualties	Percent of casualties
Head:		
Penetration	65	39. 6
Decapitation	7	4. 3
Fracture, without penetration	2	1. 2
Total	74	45. 1
Thorax:		
Penetration	60	36. 6
Mutilation	3	1. 8
Total	63	38. 4
Abdomen, penetration	12	7. 4
Lower extremity:		
Perforation	11	6. 7
Traumatic amputation	4	2. 4
Total	27	16. 5
Grand total	164	100. 0

5. In the case of extensive mutilating wounds, the cause of death was attributed to a wound of the region of the body nearest the center of the area of mutilation.

Table 230 gives the breakdown of cause of death data. Figures 287, 288, 289, 290, 291, and 292 depict typical examples of fatal wounds in aircrew casualties.

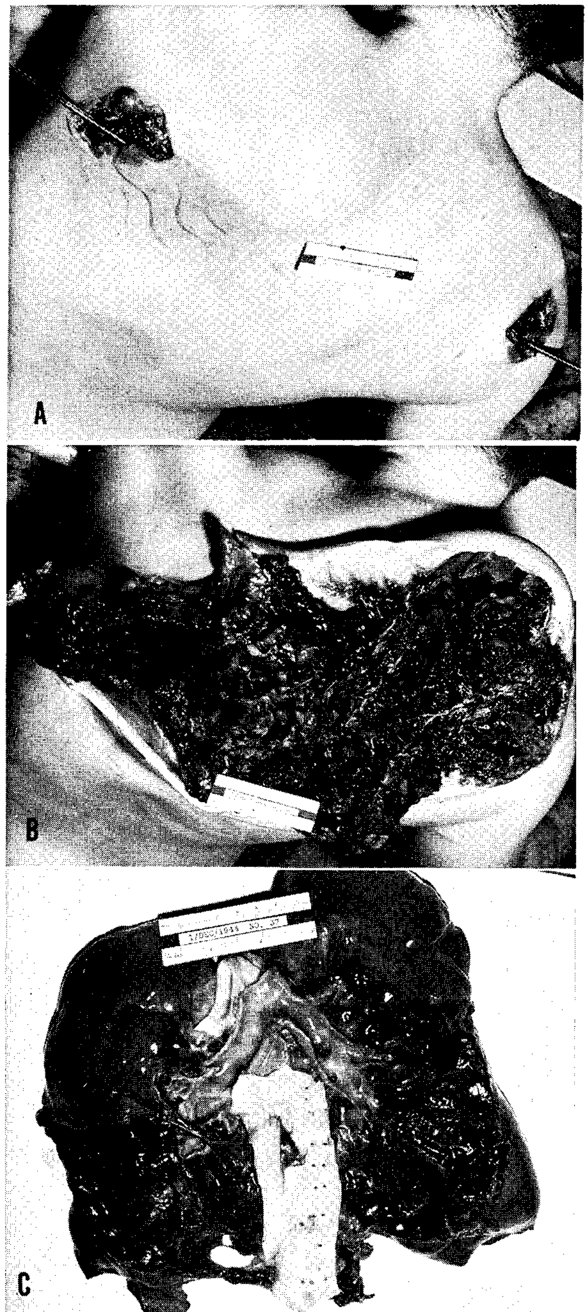
SUMMARY AND CONCLUSIONS

The survey of aircrew casualties presented here covers a period of 3 months of operational missions carried out by heavy bombers of the Eighth Air Force (D−5 to D+86). A survey of KIA casualties was continued for a further 3 months and was extended to include casualties from the Ninth Air Force and Troop Carrier Command. A total of 69,682 heavy bomber sorties (39,724 by B–17's and 29,958 by B–24's) was credited during the 3 months' period. This represents 657,096 man-combat missions completed of which 357,516 were in B–17's and 299,580 were in B–24's. During the period, 693 heavy bombers (390 B–17's and 303 B–24's) were reported "Missing-in-Action." Thus, casualty data pertaining to 6,540 (1.00 percent)



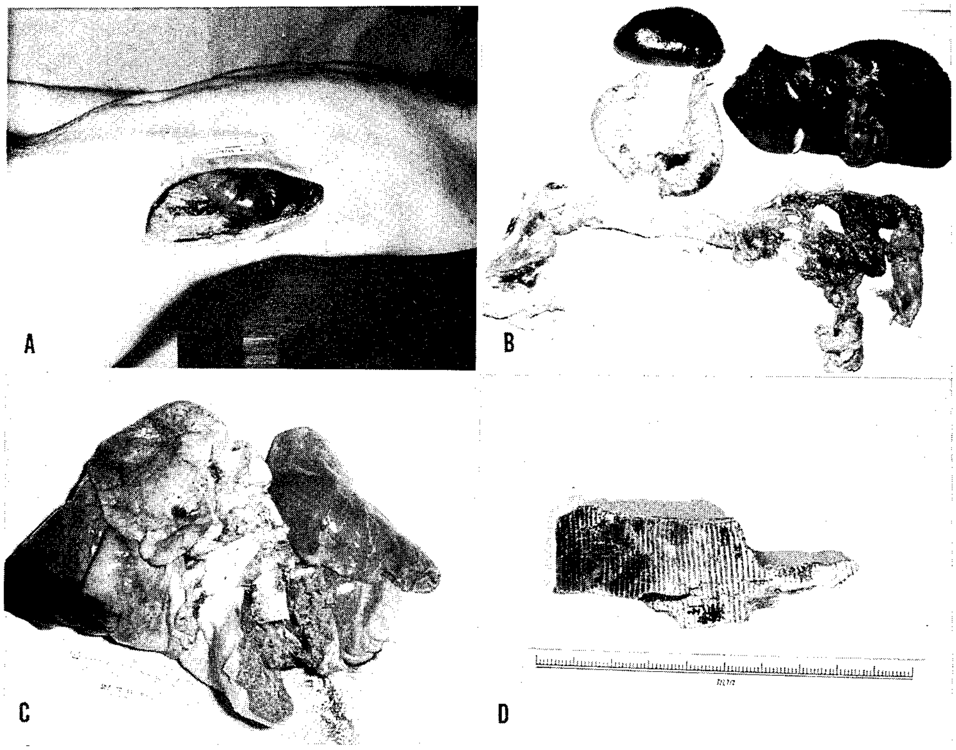
U.S. Army photos

FIGURE 287.—Radio operator in B–17 aircraft. Typical example of fatal wound in the neck region caused by large low-velocity flak fragment. A. Wound of entrance 1.5 x 4.2 cm. B. Bruised areas overlying flak fragment. C. Flak fragment in larynx. D. Flak fragment 47.30 grams.



U.S. Army photos

Figure 288.—Waist gunner in B–17 aircraft. Example of through-and-through fatal wound produced by high-velocity flak fragment. A. Wound of entrance, right (4 x 4 cm.), and wound of exit, left (4 x 7 cm.). B. Missile track laid open showing extensive mutilation of thoracic cage. C. Thoracic viscera showing widespread damage to lungs and posterior mediastinum.

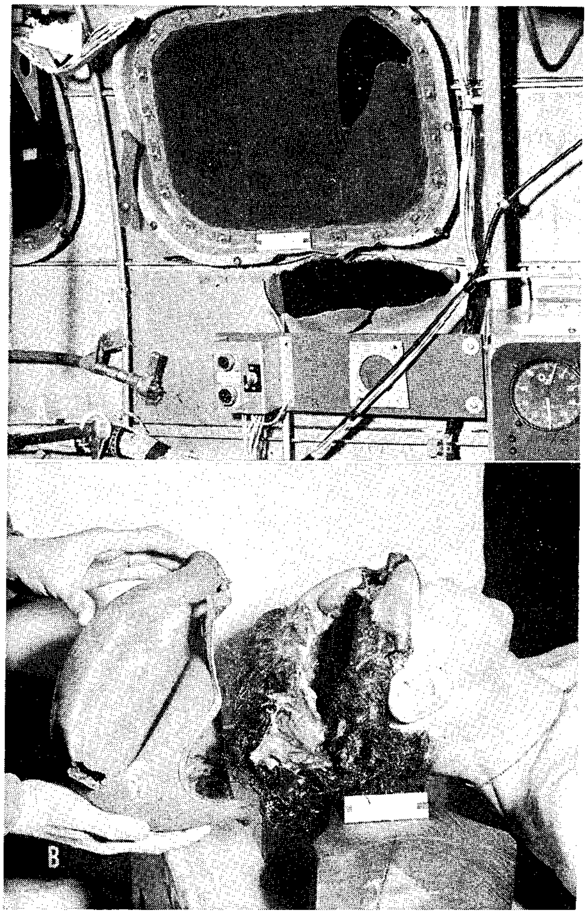


U.S. Army photos

FIGURE 289.—Radio operator in B–17 aircraft. Example of a fatal wound of the unprotected flank and extending into the chest, produced by a large low-velocity flak fragment. A. Entrance wound 5.5 x 14.7 cm. B. Damage to abdominal organs. C. Extensive laceration of heart with missile in situ. D. Flak fragment 83.66 grams.

officers and enlisted men were not available. Casualty data were available and studied on the 99 percent of aircraft and personnel that successfully completed and returned from 68,989 sorties or 650,556 man-combat missions. There were 1,117 known battle casualties sustained by the Eighth Air Force during the 3 months of the survey of whom 110 had been killed and 1,007 wounded as a result of enemy gunfire. The 1,117 casualties represent an overall casualty rate of 0.172 percent (1.72 percent per 1,000 man-combat missions completed). When distributed according to types of aircraft, the casualty rates in B–17's and B–24's were 2.10 and 1.26 per 1,000 man-combat missions, respectively. The case fatality rate was 9.8 percent and did net differ significantly for casualties in the two types of aircraft.

The ratio of MIA personnel to known casualties was approximately 6 to 1. The data pertaining to casualties among MIA personnel, could they have been included in the study, might have materially influenced the observations that have been made. Of aircrew personnel, 1 percent (10.1 per 1,000 man-combat missions) were known to be missing in action. The incidence of MIA



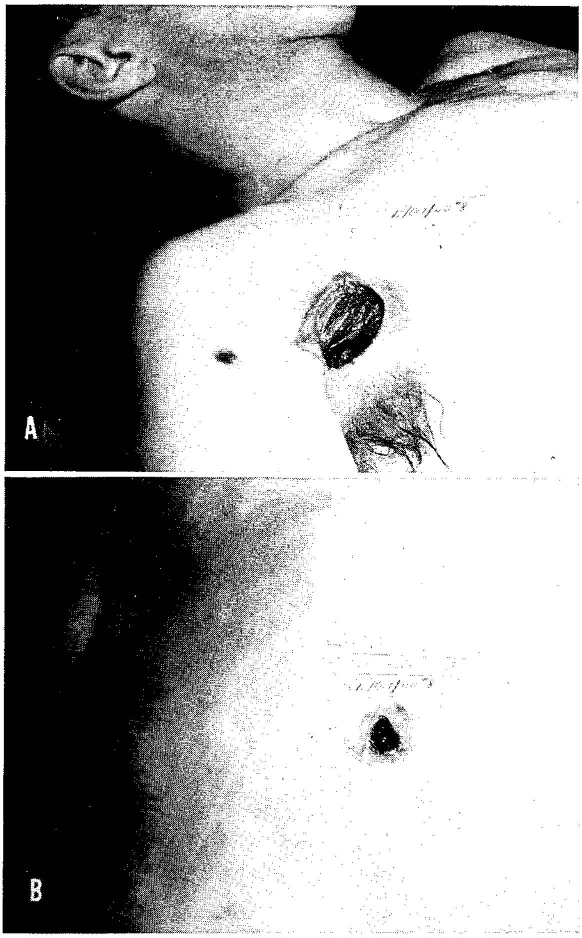
U.S. Army photos

FIGURE 290.—Navigator in B–17 aircraft. Example of fatal cranial wound due to unexploded 88 mm. higher explosive antiaircraft shell. A. Entrance hole in the nose of a B–17 aircraft of an unexploded 88 mm. high explosive antiaircraft shell. B. Fatal wound of the head produced by unexploded 88 mm. shell as it passed through the nose of a B–17 aircraft.

aircraft and personnel for the two types of bombers did not differ significantly.

Flak fragments caused 86.2 percent of the casualties. Since 7.8 percent of the casualties were due to secondary missiles, that is, those set in motion usually by flak, 94 percent of all the casualties studied may be regarded as being due to flak. Of the total casualties, 4.5 percent were caused by missiles from enemy fighter aircraft and the remaining 1.5 percent were caused by unidentified missiles.

The incidence of multiple wounds in KIA casualties during the first 3 months of the survey was 39.1 percent. This incidence increased to 50.0 percent when the KIA casualties examined during the second 3 months were included in an analysis of all KIA casualties. The increase in the multiplicity

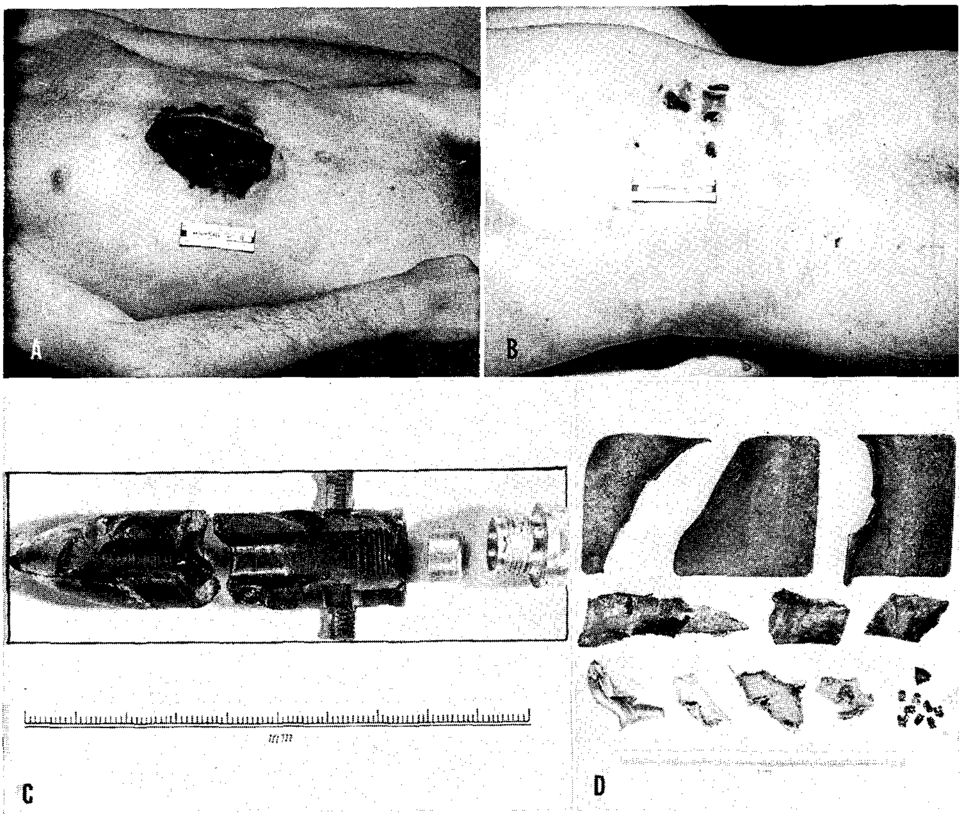


U.S. Army photos

Figure 291.—Radio operator in B–17 aircraft. Typical example of fatal wound in axillary region caused by flak fragment. A. Wound of entrance 3 x 3.6 cm. B. Wound of exit 1.5 x 2 centimeters.

of wounds may be regarded as evidence of an increase in the use of higher burst velocity shells by the enemy. Further evidence of this is given when a comparison is made of the incidence of fractures in the two samples of KIA casualties. During the first 3 months, the incidence of fractures was 85.3 percent, whereas for the 6 months the incidence of fractures increased to 91 percent.

The severity of wounds sustained by aircrew battle casualties was evaluated on the basis of time lost from flying status. The period of observation after injury was limited to 90 days. Of the total number of casualties (including the KIA), 33.8 percent were permanently lost from flying status. Of the WIA casualties, 9.8 percent lost a day or less from flying status, 25.4 percent



U.S. Army photos

FIGURE 292.—Pilot of B–24 aircraft. A. Wound of entrance 8.4 x 13.2 cm. B. Multiple wounds of exit. C. Partial reconstruction of a 20 mm. armor-piercing incendiary cannon shell from retained fragments, 75.46 gm. D. Pieces of body armor and other personal equipment in fatal wound.

lost a week or less, 55.9 percent lost a month or less, and 17.5 percent lost from 1 to 3 months.

Approximately 70 percent of the casualties in B–17's occurred at an altitude of 24,000 feet or above, whereas 92 percent in B–24's occurred at 23,000 feet or below.

Of all WIA aircrew battle casualties, 90 percent received adequate surgical treatment in hospitals within 4 hours after they were wounded.

Since by far the majority of casualties was caused by flak, an independent analysis of all flak casualties was made. Their distribution according to combat position is shown in the order of frequency (table 231). Heavy bomber aircraft formerly carried two waist gunners, which probably accounts for the highest incidence of casualties in that combat position. The lowest incidence of casualties in the ball turret gunner's position is at least partially due to the fact that only B–17 aircraft carry a ball turret gunner.

No fragments smaller than 1 gm. were recovered from fatal wounds due to flak in KIA casualties; 92.6 percent of those recovered weighed 5 gm. or more. In WIA casualties, 39.1 percent of the fragments weighed less than 1 gram.

Plexiglas fragments set in motion by other missiles produced 88 wounds; of these 85 were on the exposed regions of the face and neck and 3 were on the forearms. There were no Plexiglas wound fatalities. Of those wounded by Plexiglas fragments, 92 percent were returned to flying duty within 90 days. It would appear that protection of the eyes and circumorbital regions with any relatively thin, shatterproof, transparent material would probably have eliminated most casualties due to Plexiglas fragments.

TABLE 231.—*Distribution of flak casualties sustained according to combat position, in order of frequency*

Order of frequency	Position of—	
	WIA casualty	KIA casualty
1	Waist gunner	Waist gunner.
2	Bombardier	Tail gunner.
3	Navigator	Bombardier.
4	Tail gunner	Navigator.
5	Radio operator	Top turret gunner.
6	Top turret gunner	Radio operator.
7	Pilot	Pilot.
8	Copilot	Ball turret gunner.
9	Ball turret gunner	Copilot.

Of the casualties due to missiles from fighter aircraft, 88 percent were produced by 20 mm. shells. The tail gunner was found to be the most vulnerable combat position, while bombardier and navigator were the least vulnerable to enemy fighter aircraft. This is the reverse of the relative vulnerability of the same combat positions to flak and is in accordance with the findings of the Operational Research Section, Eighth Air Force, that enemy fighter aircraft usually attack heavy bombers from the rear.

A comparison is made of the regional distribution of wounds in flak casualties with and without protective body armor. From table 232, it may be seen that the incidence of flak wounds of the trunk has fallen from 13.3 percent in unarmored casualties to 8.2 percent (38 percent decrease) in casualties wearing body armor. It is apparent that the thoracic and abdominal regions have been protected by the wearing of body armor. It has been observed that the neck and axillary regions are the most highly vulnerable to penetration by enemy missiles on men wearing body armor.

The separation of casualties into "unarmored" and "armored" in table 232 does not hold so far as the occurrence of wounds of the head is concerned. Data pertaining to the protective value of head armor (steel helmet) were not sufficient to evaluate statistically.

TABLE 232.—*Mean projected body areas and regional distribution of flak wounds in unarmored and armored battle casualties*

Region	Mean projected area of region	Wounds in unarmored casualties	Wounds in armored casualties
	Percent	*Percent*	*Percent*
Head	12	16. 1	16. 1
Chest	16	9. 8	5. 5
Abdomen	11	3. 5	2. 7
Extremities:			
Upper	22	26. 4	32. 5
Lower	39	44. 2	43. 2
Total	100	100. 0	100. 0

CHAPTER X

Directional Density of Flak Fragments and Burst Patterns at High Altitudes[1]

Allan Palmer, M.D.

GERMAN 88 MM. HIGH EXPLOSIVE ANTIAIRCRAFT SHELL

The material in this chapter was obtained at the same time that a survey of missile casualties was being conducted by the Medical Operational Research Section, Professional Services Division, Office of the Chief Surgeon, ETOUSA (p. 547). The survey covered all of the battle casualties sustained by the Eighth Air Force during a 6 months' period beginning on 1 June 1944. More than 99 percent of the flak fragments recovered during the survey were probably from German 88 mm. HEAA (high explosive antiaircraft) shells. Only two fragments observed were definitely identifiable as fragments from shells larger than 88 mm. Because of this, a discussion of German ammunition will be limited to the 88 mm. shell.

Details of the structure of the shell are contained in USSTAF Ordnance Memorandum No. 5–6, 29 March 1944, and are shown in figure 293. The filled weight of the shell is about 21½ pounds, the average weight of the filling is approximately 2 pounds, and the charge-weight ratio is 8.6 percent. The body of the shell which gives rise to the majority of the fragments is composed of 0.72 percent carbon steel and its wall averages nine-sixteenths of an inch in thickness. The mean burst velocity of fragments observed in trials carried out at Millersford was 2,280 f.p.s. The velocity of the projectile at the instant of burst at the altitude at which the shell is fired at heavy bomber aircraft is estimated to range from 1,000 to 2,000 f.p.s., being greatest when the angle of fire is nearest vertical and lowest the more the angle of fire deviates from the vertical.

In order to bring out certain points with respect to the flak risk run by aircrew personnel, it is necessary to consider certain elementary facts relating to the manner in which the shell wall breaks up into fragments. For the sake of simplicity, certain properties of the static burst of a completely spherical projectile breaking up over its entire surface into fragments of uniform weight and size, all traveling at the same velocity, will be considered.

[1] The mathematical treatment of the data in this report was provided by the combined efforts of Prof. Sir Ronald A. Fisher, Sc. D., F.R.S., Department of Genetics, University of Cambridge, Cambridge, England, and Prof. F. Yates, Sc. D., F.R.S., Department of Statistics, Rothamsted Experimental Station, Harpenden, Herts, England.

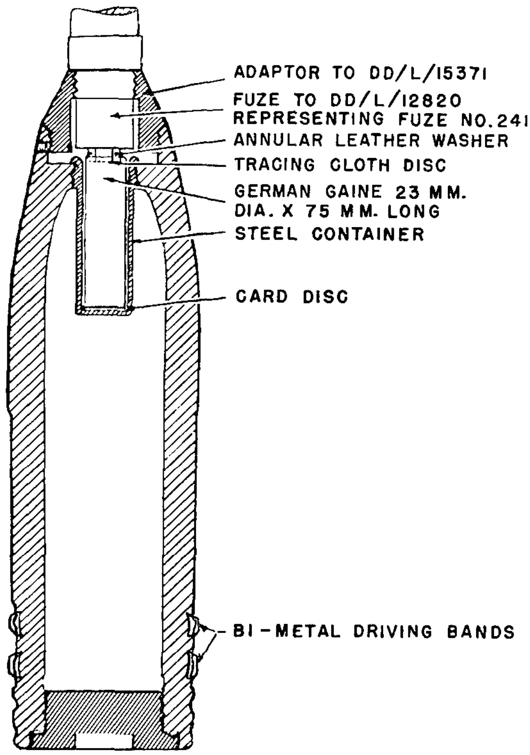


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FIGURE 293.—Structure of German 88 mm. HEAA shell.

Considering the distribution of fragments from such a projectile after they had traveled, say, 100 feet from the point of burst, would amount to considering the distribution of fragments in a sphere whose radius was 100 feet. Since the projectile broke up uniformly, the relative density of fragments—that is, the number of fragments per unit area on the surface of the sphere—would be the same all over the sphere. Since, however, the annular bands subtended on the surface of the sphere, per unit angle at its center with respect to the equatorial plane, decrease in area as one proceeds from the "equator" to its "north or south pole," the number of fragments in each annulus will decrease accordingly in spite of the fact that the density per unit surface area remains the same. This is shown in table 233 and figure 294. Column 1 of the table lists the annular zones with respect to the equatorial plane in 30° bands. Column 2 indicates the percent of fragments which will be found in successive annular zones on the surface of the sphere, if the boundary of each of these zones subtends an angle of 30° at the center of the sphere. Column 3 is merely a statement that the density per unit area on the surface of the sphere is constant.

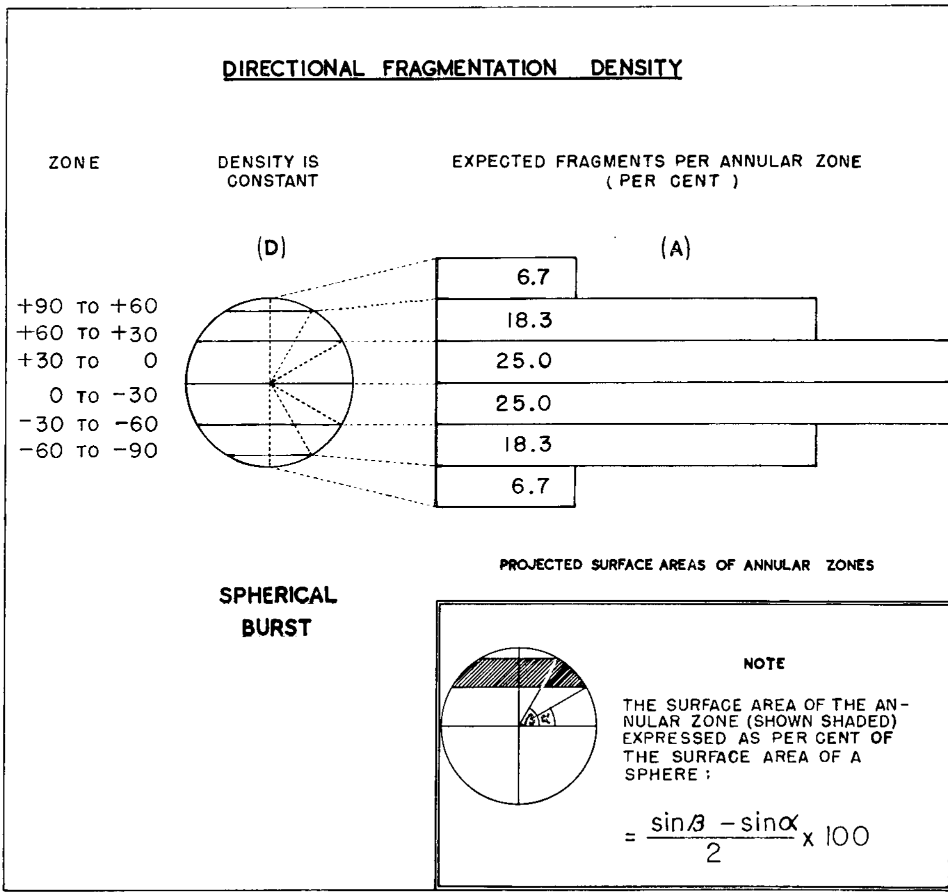

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FIGURE 294.—Diagrammatic representation of directional fragmentation density of a spherical burst.

TABLE 233.—*Directional fragmentation densities for a static spherical burst*

(1) Annular zone (with respect to equatorial plane)	(2) Expected fragments per annular zone (percent) (n) and (A)	(3) Density per area on surface of sphere (D)
Degree		
90 to 60	6. 7	1
60 to 30	18. 3	1
30 to 0	25. 0	1
0 to —30	25. 0	1
—30 to —60	18. 3	1
—60 to —90	6. 7	1

These figures provide a basis for standardizing values for fragmentation density for shells of different types in different zones around the burst. Such standardized values will be referred to in the following paragraphs as "directional fragmentation densities."

In actual fact, the concept of a spherical burst is entirely theoretical. Antiaircraft shells are not spherical, and their fragments are dispersed from the bursting projectiles in annular zones of varying density. This is shown in tables 234, 235, and 236 and in figure 295 which give the results of certain

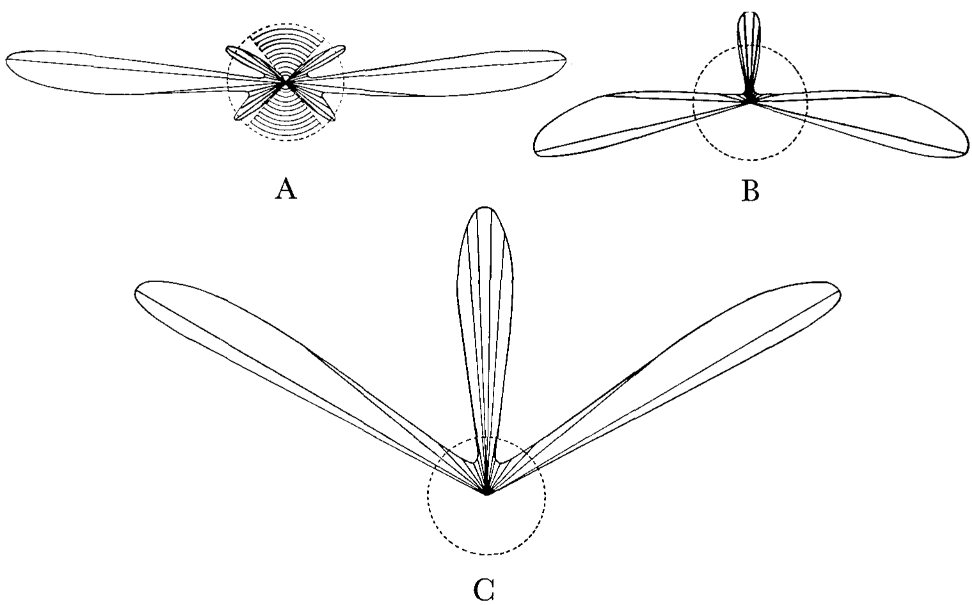

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FIGURE 295.—Directional fragmentation density. A. 88 mm. shellburst (static, nose. down; density in shaded zones not observed). B. 90 mm. shellburst (static, nose up) C. 90 mm. shellburst (moving vertically 2,000 f.p.s.).

trials in which AA shells were detonated experimentally in such a way that it was possible to measure the number of fragments in different annular zones with respect to the equatorial plane of the shell (that is, the equatorial plane being at right angles to the axis of the shell and cutting through its center).

Figure 294, constructed from the data in table 233, may be regarded as the diagrammatic representation of a spherical burst from which there is a uniform distribution of fragments and for which the relative directional fragmentation densities (D) are the same. The values of 1 for the densities in all directions are shown by the constant length of the radii of the circle (representing a sphere) in zones of 30° with respect to the equatorial plane. The values under A (column 2 of table 233) are those areas of the annular bands expressed in percentages of the total area of the sphere, subtended

by 30° angles at its center with respect to the equatorial plane. These areas are projected in figure 294.

Consider next a variation from a spherical burst. For example, a value of 5 in column 3 of table 233 for a given annular zone would mean a density of fragments per unit area on the surface of the sphere relatively five times as great as would be expected for a spherical burst. The fivefold increase in this zone would involve relative decreases in densities in other zones. The values for directional fragmentation density as used are representations of densities per unit solid angle. Because of the lack of complete fragmentation data for any of the burst patterns to be discussed, a relative value as opposed to an absolute value is desirable.

Fragmentation trials on three rounds of the German 88 mm. HEAA shell were conducted at Millersford.[2] The shells were set up vertically, nose down, 5 feet above the ground. For each detonation, two sets of three strawboard panels, 10 feet high by 40 and 60 inches wide, were placed vertically 5 feet and 10 feet from the shell and so staggered that they did not overlap each other. For each trial, the number of strikes was counted on the panels in such a way as to separate the strikes that occurred at 10-inch intervals above and below the equatorial plane of the center of the shell. Column 1 of table 234 indicates those zones in inches. Column 2 specifies those zones in terms of the angle each subtended at the center of the shell. Columns 3 and 4 show the number and percent of fragments observed in each zone.

TABLE 234.—*Directional fragmentation densities of German 88 mm. HEAA shell*

(1) Zone	(2) Angle subtended by 10-inch zone	(3) Number of fragments observed	(4) Percent (n) of fragments observed	(5) Corresponding values for spherical burst (percent) (A)	(6) Density $\left(D=\frac{n}{A}\right)$
Inches					
50 to 60	5°12′	24	2. 0	3. 3	0. 6
40 to 50	6°7′	46	3. 8	4. 3	. 9
30 to 40	7°7′	80	6. 5	5. 3	1. 2
20 to 30	8°8′	33	2. 7	6. 5	. 4
10 to 20	8°58′	37	3. 1	7. 6	. 4
0 to 10	9°28′	495	40. 4	8. 3	4. 9
−10 to 0	9°28′	253	20. 5	8. 3	2. 5
−20 to −10	8°58′	63	5. 1	7. 6	. 7
−30 to −20	8°8′	54	4. 4	6. 5	. 7
−40 to −30	7°7′	61	4. 9	5. 3	. 9
−50 to −40	6°7′	54	4. 5	4. 3	1. 1
−60 to −50	5°12′	21	2. 1	3. 3	. 6
	90°0′	1, 221	100. 0	70. 6	

NOTE.—Table, based on data obtained at Millersford trials, shows conversion of fragment distribution in 10-inch zones at 5 feet detonation distance into relative directional densities.

[2] Armament Research Department Explosives Report 224/43, October 1943.

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A value for directional fragmentation density in any zone may be obtained from the equation

$$D=\frac{n}{A}$$

in which n is the number of fragments observed in the zone, expressed as the percentage of the total number of fragments observed, and A is the area of the annular band on the surface of a sphere subtended by an angle at its center, expressed as the percentage of the total surface area of a sphere. Values for A may be obtained from the equation entered as a note in figure 294.

It should be emphasized that figure 294 is a two-dimensional drawing representing a three-dimensional burst pattern. Thus, the radius in figure 294 that deviates 30° from the vertical would describe a relatively small cone subtending the "north polar" surface of a sphere, whereas the radius that makes a 30° angle with the equatorial plane would describe an annular zone on the surface of a sphere comparable to the northern half of the Torrid Zone on the surface of the earth.

In the Millersford trials, no observations were made about the densities of fragments projected upward from the base and downward from the nose of the shell. If the burst is regarded as a spherical projection of fragments from the center of the projectile, the unobserved zones (shaded in fig. 295A) above and below the 90° zone, in which observations on fragmentation were not made, account for 29.4 percent of the surface area of the sphere. The 1,221 fragments noted in table 234, while they represent 100 percent of the observed number of fragments dispersed by an 88 mm. shell, were dispersed in directions which represent only 70.6 percent of what would be expected for a spherical burst (column 5 of table 234). Previous experience has shown that the number of fragments dispersed upward and downward in the unobserved zones in similar experiments is negligible.

Figure 295A shows for comparison with a spherical burst (fig. 294) the burst pattern of a nose-down 88 mm. shell detonated statically. It is pointed out again that the lengths of the lines or radii from the point of burst (D, column 6 in table 234) are measures of relative directional fragmentation densities.

A report by the Operational Analysis Section, Mediterranean Allied Air Forces [3] gives the observed data pertaining to fragment distribution from a statically detonated, nose-up, U.S. 90 mm. HE shell. Tables 235 and 236 are similar to table 234 except that the annular zones in which fragments were counted are specified only by the angles by which they are subtended at the center of the burst (column 1).

[3] Report, Operational Analysis Section, Mediterranean Allied Air Force, subject: The Physical Basis for Evasive Action to Reduce Flak Losses, May 1944.

TABLE 235.—*Directional fragmentation densities for U.S. 90 mm. shell, static burst*

(1) Zone (with respect to the equatorial plane)	(2) Number of fragments observed	(3) Percent (n) of fragments observed	(4) Corresponding values for spherical burst (percent) (A)	(5) Density $\left(D=\frac{n}{A}\right)$
−90° to −20°	0	0	32. 90	0
−20° to −5°	441	50. 9	12. 74	3. 95
−5° to 10°	300	34. 6	13. 04	2. 66
10° to 20°	39	4. 5	8. 42	. 54
20° to 40°	40	4. 6	15. 04	. 31
40° to 60°	20	2. 3	11. 16	. 21
60° to 70°	7	. 8	3. 68	. 22
70° to 80°	10	1. 2	2. 25	. 53
80° to 85°	7	. 8	. 57	1. 40
85° to 90°	3	. 3	. 19	1. 58
	867	100. 0	100. 0	

TABLE 236.—*Directional fragmentation densities for U.S. 90 mm. HE shell, moving burst, 2,000 f.p.s. vertically*

(1) Zone (w th respect to the equatorial plane)	(2) Number of fragments observed	(3) Percent (n) of fragments observed	(4) Corresponding values for spherical burst (percent) (A)	(5) Density $\left(D=\frac{n}{A}\right)$
90° to 25°59′	0	0	71. 90	0
25°59′ to 35°35′	441	50. 9	7. 20	7. 07
35°35′ to 44°40′	300	34. 6	6. 06	4. 03
44°40′ to 50°33′	39	4. 5	3. 46	1. 30
50°33′ to 62°02′	40	4. 6	5. 55	. 83
62°02′ to 73°18′	20	2. 3	3. 73	. 62
73°18′ to 78°58′	7	. 8	1. 18	. 68
78°58′ to 84°27′	10	1. 2	. 69	1. 74
84°27′ to 87°13′	7	. 8	. 17	4. 70
87°13′ to 90°00′	3	. 3	. 06	5. 00
	867	100. 0	100. 0	

The divergence of the burst pattern of a shell from the burst pattern of a theoretical spherical projectile can easily be demonstrated if one first calculates the percent of all fragments which would be expected in the area of each annular zone of a sphere which would be subtended by the angles indicated in column 2 of table 234 and column 1 of tables 235 and 236. These percentages are determined in the same way as those calculated for column 2 of table 233. The values obtained are shown in column 5 of table 234 and column 4 of tables 235 and 236. Since the density of strikes per unit area in the theoretical spherical burst is unity, the divergence of the actual fragment pattern

of a shell for each annular zone is given by the ratio of the percent of fragments observed in each zone to the percent of fragments expected in that zone had the burst been that of the theoretical spherical projectile. These ratios, which are referred to as the directional fragmentation densities, are shown for the three projectiles considered in columns 6, 5, and 5, of tables 234, 235, and 236, respectively.

Figure 295B and C shows the burst patterns of the U.S. 90 mm. shell detonated statically and in motion. The static burst patterns of the German 88 mm. and the U.S. 90 mm. shells are approximately similar when one or the other is inverted. The apparent differences in figure 295A and B are due to the fact that the 88 mm. was nose down while the 90 mm. was nose up.

AIRCRAFT BATTLE DAMAGE DATA

Density of Flak Hits on Aircraft

If all AA shells were fired vertically, the burst pattern shown in figure 295C would represent the directional fragmentation densities of flak in the atmosphere. This figure would also represent the relative importance of the different directions from which protection would be required by aircrew personnel in heavy bombers. However, an enemy AA battery may fire at a formation of heavy bombers throughout approximately 12 miles (3 minutes) of the bombers' flight course and is actually unable to fire directly vertically. Therefore, fragments from bursting projectiles from one battery are likely to produce a composite burst pattern that differs from that of shells bursting only in a vertical orientation.

It was thought desirable to construct a composite burst pattern that would represent the aggregate of flak bursts that actually occur under operational conditions. In order to do this, the frequency of flak hits on plane horizontal and vertical surfaces of a sample of aircraft was determined. All the B–17 and B–24 aircraft that were hit by flak and returned to the United Kingdom during July 1944 were examined. If the number of MIA aircraft due to flak damage were sufficiently great, the distribution of flak hits on them might materially influence the observations made on the July sample of aircraft. Accurate data as to how many MIA aircraft were lost because of damage due to flak were not available. However, 15 percent of MIA personnel were evaders who returned to the United Kingdom and who were interrogated by representatives of the Operational Research Section, Eighth Air Force. It is estimated on the basis of information obtained from the personnel questioned that approximately 60 percent of both types of MIA aircraft were lost because of damage due to flak during July 1944. During that month, 134 B–17's and 107 B–24's were missing in action. Thus, 3,053 B–17 aircraft, of which 2,973 were examined and of which approximately 80 (2.6 percent) were missing in action, were possibly damaged by flak. Also, 958 B–24 aircraft, of which 894 were examined and of

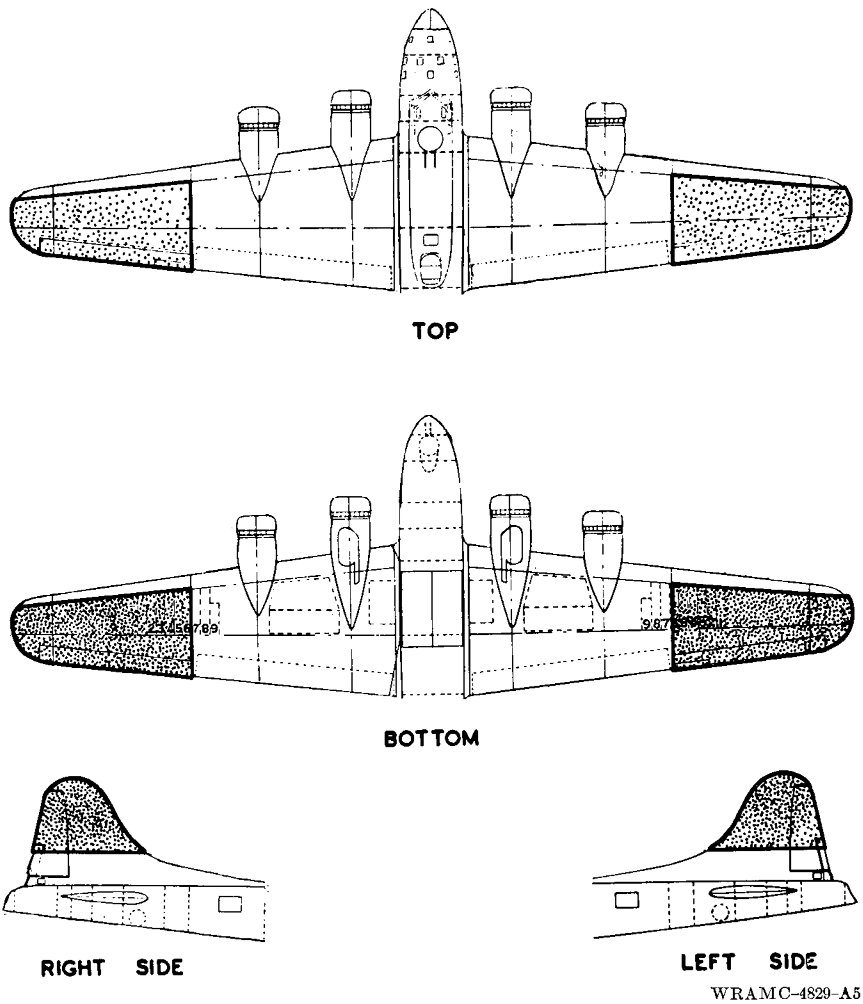


FIGURE 296.—Location of flak hits on 2,961 B-17 aircraft, plane surfaces only.

which approximately 64 (6.7 percent) were missing in action, were possibly damaged by flak. It is unlikely that the small incidence of MIA flak-damaged aircraft, could they have been included in the analysis, would have greatly changed the observations pertaining to either type of aircraft.

Only the flat portion of the main wings lateral to the numbers 1 and 4 engines and the "unprotected" surfaces of the vertical stabilizers of both aircraft were used for these observations. Figures 296 and 297 show the location of flak hits on the plane surfaces of the two types of aircraft. The surface areas were determined by planimeter measurements of scale drawings of the aircraft and are given in column 1 of table 237. This table shows the data obtained from the battle damage reports for 2,961 B-17's and 888 B-24's. The manner of

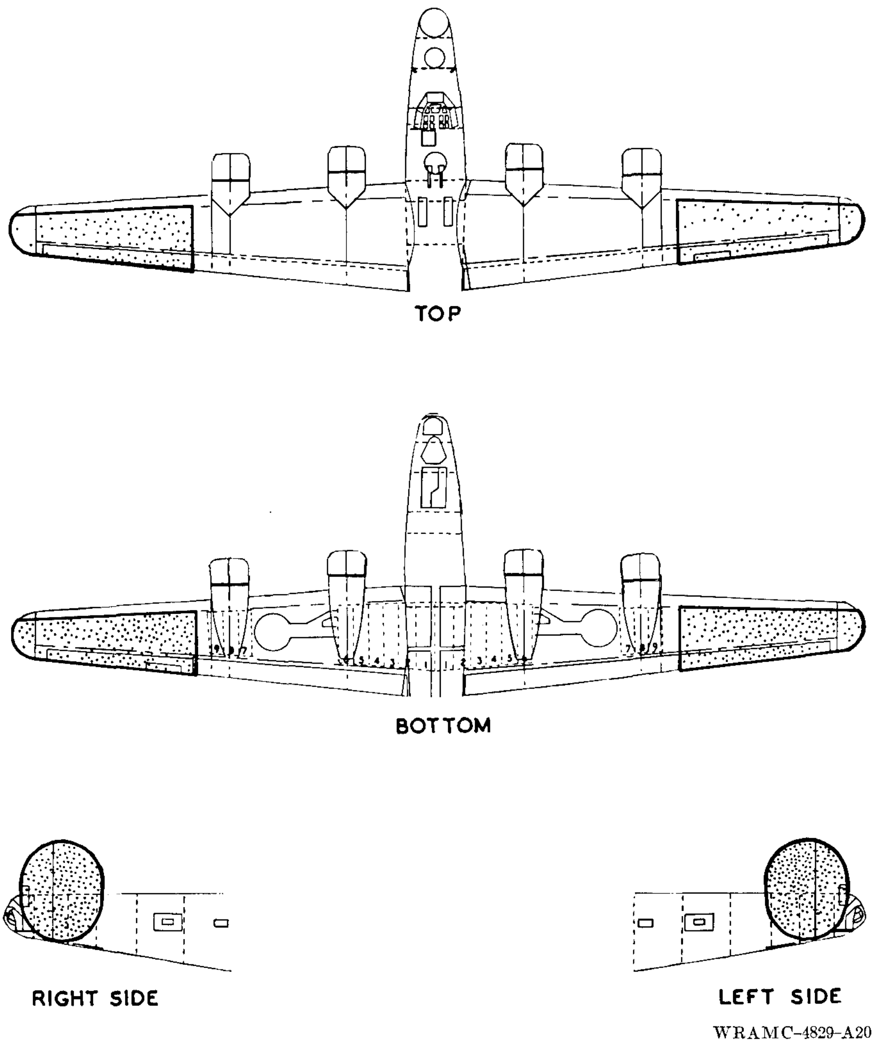


FIGURE 297.—Location of flak hits on 888 B–24 aircraft, plane surfaces only.

calculating the "standardized" densities of hits on plane surfaces was the same as that given for the calculation of "standardized" directional fragmentation densities, and the values obtained are given in column 6 of table 237.

The figures in columns 3 and 6 of table 237 show that the greatest density of hits occurred on the bottom surfaces of B–17 aircraft. The density of hits on vertical surfaces was only slightly less, whereas the density of hits on top surfaces was approximately one-third as great as that on bottom or vertical surfaces.

Corresponding figures for B–24 aircraft (columns 3 and 6) show that vertical surfaces suffered the greatest density of flak hits. The latter was 54 percent

TABLE 237.—*Densities of flak hits on the plane surfaces of 2,961 B–17 and 888 B–24 aircraft, respectively, during July 1944*

Surface struck	(1) Area (square feet)	(2) Hits	(3) Number of observed hits [1]	(4) Percent (n) observed hits [1]	(5) Percent (A) expected hits assuming random distribution	(6) Standardized densities $\left(D=\frac{n}{A}\right)$
B–17 aircraft:						
Top	368	487	0. 45	6. 4	16. 7	0. 38
Bottom	368	1, 554	1. 43	20. 3	16. 7	1. 22
Sides	156	598	5. 16 (1. 29)	73. 3	66. 6	1. 10
Total	892	2, 639	7. 04	100. 0	100. 0	
B–24 aircraft:						
Top	272	143	0. 59	5. 8	16. 7	0. 35
Bottom	272	327	1. 35	13. 2	16. 7	. 79
Sides	194	359	8. 32 (2. 08)	81. 0	66. 6	1. 22
Total	738	829	10. 26	100. 0	100. 0	

[1] Data calculated per square foot per 1,000 aircraft.

NOTE.—Figures in parentheses for one side only.

greater than the density of hits on bottom surfaces and three and a half times the density of hits on top surfaces. The figures in column 3 (table 237) show in general a slightly greater density of flak hits per unit surface area on B–24 than on B–17 aircraft. There was an average density of 1.00 hit per square foot on B–17's as compared with 1.26 per square foot on B–24's.

Directional Density of Flak in Relation to Distribution of Observed Hits

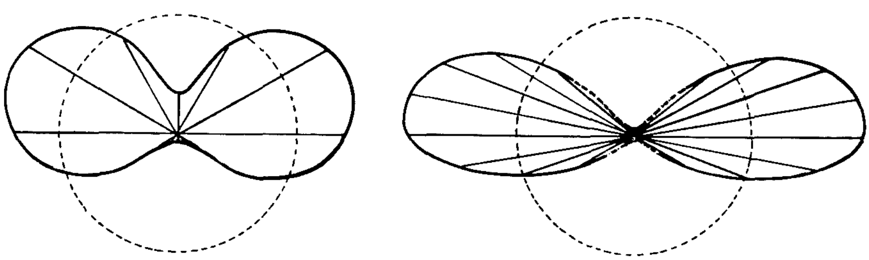
The densities of flak hits on different plane surfaces cannot be regarded directly as representing the densities of fragments proceeding in space in given directions. It stands to reason that only a small part of the total density of hits on a plane surface are caused by fragments which struck it normally. If the densities of flak hits on a large number of aircraft, the plane surfaces of which were oriented in several different directions in space (say six), were known, it would be possible to calculate the directional fragmentation densities of flak fragments to which the aircraft were exposed. With plane surfaces oriented in three directions only, as in the present case, the data are not adequate to make an exact determination of directional fragmentation densities. In other words, a number of different sets of directional fragmentation densities

can be calculated, all of which will give the densities of hits on plane horizontal and vertical surfaces which were actually observed.

One such set of directional fragmentation densities, which may be regarded as the distribution of flak in the atmosphere to which B–17 aircraft were exposed, is shown diagrammatically in figure 298A. The standardized values of $r(\theta)$ in table 238 were calculated from the equation

$$r(\theta) = a+b \cos \theta+c \cos^2 \theta+d \cos^3 \theta$$

in which a, b, c, and d are constants that were solved so that the equation would fit the observed densities of hits on the plane horizontal and vertical surfaces of the aircraft. They are represented in the composite burst pattern (fig. 298A) by the length of the radii from the point of burst.



A B

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FIGURE 298.—Directional fragmentation density. A. Composite flak burst, constructed from the flak hits on the plane horizontal and vertical surfaces of 2,961 B–17 aircraft. B. Composite flak burst, constructed from the flak hits on the plane horizontal and vertical surfaces of 888 B–24 aircraft.

TABLE 238.—*Directional fragmentation densities of flak against B–17 aircraft*

(1) Direction (θ)	(2) Standardized density $r(\theta)$
Degree	
[1] 0	0. 08
30	. 12
60	. 72
[2] 90	1. 40
120	1. 48
150	. 88
[3] 180	. 32

[1] Vertically downward.
[2] Horizontally.
[3] Vertically upward.

The number of flak fragments striking an object will vary directly with the surface area it presents and inversely with the square of the distance from the point of a burst. The densities of hits will be further influenced by the shape of the target and its movement in space. The figures in column 3 of table 237 are absolute values and those in column 6 of the same table are standardized values for the densities of hits on the plane surfaces of B–17 aircraft. In contrast, the figures in column 2 of table 238 represent relative values for directional fragmentation densities of fragments dispersed in space from the point of a burst. These values are represented graphically in the composite burst pattern shown in figure 298A. Relative directional fragmentation densities are measures of the densities of fragments dispersed in different directions toward aircraft and in this case may be regarded as constant for the altitude at which the B–17's operate. These directional fragmentation densities will not vary or be influenced by any of the factors which determine variations in the density of hits received on different surfaces of the B–17's.

The mathematical form chosen to determine relative values for directional fragmentation densities of fragments which would account for the observed distribution of hits displayed in table 237 (for B–24 aircraft)

$$r(\theta) = a+b \cos \theta+c \cos^2 \theta+d \cos^3 \theta+e \cos^4 \theta+f \cos^5 \theta$$

has the defect that it does not immediately yield a reasonable curve to account for the observed densities of hits. This failure is not necessarily due to any special feature of the directional fragmentation density distribution for the B–24. The standardized values of $r(\theta)$ in table 239 are the "smoothed" values calculated from the equation.

Figure 298B is a diagrammatic representation of the values in column 2 of table 239. It shows a pattern of directional fragmentation densities which will account for the observed densities of hits on B–24 aircraft. The smoothed parts of the curve are indicated by dotted lines.

Density of Flak Hits on Fuselages of Aircraft

It is the hits on fuselages of aircraft which principally cause casualties, and therefore it was thought worthwhile to determine the densities of flak hits on the fuselages of the two types of aircraft. Actually, the standardized values for such hits should agree with those for hits on plane surfaces. Flak hits on MIA aircraft, while they might not have influenced the observed densities and distribution on plane surfaces, might materially affect the observed density and distribution of hits on the more vital fuselage surfaces, could they have been included in the observations. Differences could be due in part to the personal error introduced by the engineer officer who makes a record of flak damage to an aircraft and who has to distinguish between hits on the top and side or side and bottom of a tapering cylindrical structure whose curved surfaces cannot readily be demarcated from each other.

TABLE 239.—*Directional fragmentation densities of flak against B–24 aircraft*

(1) Direction (θ)	(2) Standardized density $r(\theta)$
Degree	
[1] 0	0. 01
30	. 01
40	. 03
50	. 08
60	. 52
70	1. 06
80	1. 60
[2] 90	1. 97
100	1. 95
110	1. 75
120	1. 32
130	. 79
140	. 33
150	. 09
[3] 180	. 03

[1] Vertically downward.
[2] Horizontally.
[3] Vertically upward.

However, the greatest differences are more likely to be due to "selection." In general, the greatest density of hits by flak on certain regions of the fuselage vital for an aircraft's safe return to the United Kingdom could not be included in the observations. The sample of aircraft studied for hits on the fuselage would be biased in favor of aircraft struck in regions of the fuselage not vital to the aircraft's return.

Column 6 of table 240 gives the standardized densities of flak hits on the fuselages of B–17 and B–24 aircraft. The projected surface areas chosen for the observations do not include the bomb bay or those portions of the sides of the fuselage protected by the main wings. The samples of 2,973 B–17 and 894 B–24 aircraft used include the 2,961 B–17's and 888 B–24's referred to previously. Figure 299 shows the location of flak hits on the projected surfaces for which the relative densities were determined.

Table 240 for B–17's shows a somewhat different order of densities of fuselage hits when compared with hits on plane surfaces; that is, the greatest density appears to be on the sides instead of on the bottom of the fuselage. The ratio of densities for hits on top and bottom surfaces is 1:1.8 as compared with 1:3.2 for densities of hits on plane surfaces, and the density of hits on the sides is twice that for hits on the bottom. Table 240 for B–24's also shows the greatest density of hits on the sides of the fuselage and a change in the ratio of densities on top and bottom surfaces from 1:2.3 to 1:0.7. The deficiencies of hits on bottoms of fuselages, as shown by decreases in the ratios

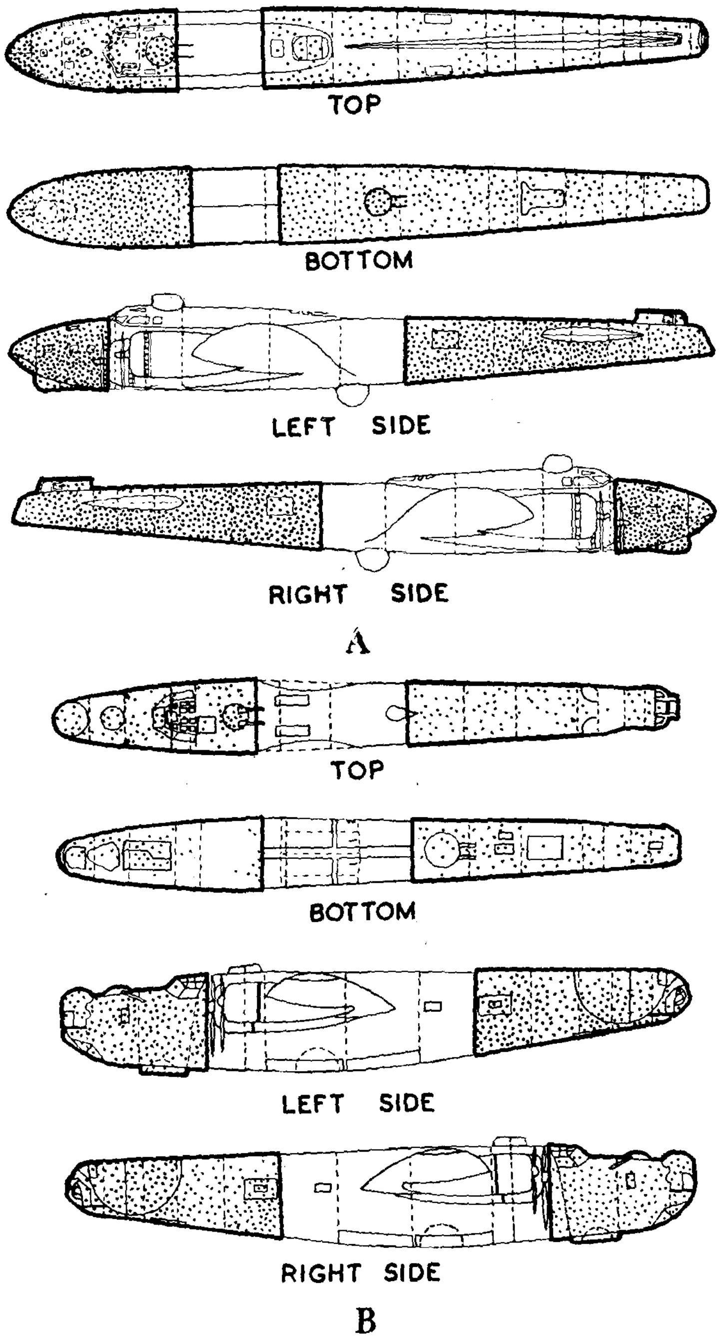

FIGURE 299.—Location of flak hits, fuselages only, on 2,973 B-17 and on 894 B-24 aircraft, respectively. A. B-17 aircraft. B. B-24 aircraft.

of top to bottom hits for both types of aircraft, may be regarded as hits sustained by MIA aircraft. In other words, aircraft shot down by flak probably sustained hits chiefly on the bottoms of fuselages. Could these hits have been included in the observations, they probably would be sufficient to restore the observed ratios of top to bottom fuselage hits so that they would correspond to the ratio of top to bottom plane surface hits. The differences observed between the densities of hits on plane and fuselage surfaces of all aircraft will be compared later with the differences between the densities on the plane and fuselage surfaces of casualty-bearing aircraft.

TABLE 240.—*Densities of flak hits on fuselages of 2,973 B–17 and 894 B–24 aircraft, respectively, during July 1944*

Surface struck	(1) Projected area (square feet)	(2) Hits	(3) Number of observed hits [1]	(4) Percent (n) observed hits [1]	(5) Percent (A) expected hits assuming random distribution	(6) Standardized densities $\left(D=\frac{n}{A}\right)$
B–17 aircraft:						
Top	408	293	0. 24	5. 8	16. 7	0. 35
Bottom	408	537	. 44	10. 6	16. 7	. 63
Sides	430	1, 106	3. 48 (. 87)	83. 6	66. 6	1. 26
Total	1, 246	1, 936	4. 16	100. 0	100. 0	
B–24 aircraft:						
Top	270	170	. 70	10. 6	16. 7	. 63
Bottom	270	120	. 50	7. 6	16. 7	. 46
Sides	540	653	5. 4 (1. 35)	81. 8	66. 6	1. 23
Total	1, 080	943	6. 60	100. 0	100. 0	

[1] Data calculated per square foot per 1,000 aircraft.

NOTE.—Figures in parentheses for one side only.

Density of Flak Hits on Casualty-Bearing Aircraft

In a selected sample of casualty-bearing aircraft, one might expect to find an increase in the number and variations in the distribution of flak hits on all surfaces generally. The casualty-bearing portion of the aircraft, that is, the fuselage, in a sample selected for casualties might be expected to show the greatest increases in density and variations in the distribution of hits. The observed relationship between flak hits and casualties is likely to be greatly different from observations that would include MIA flak-damaged casualty-bearing aircraft. The fatality rate in MIA aircrew personnel is known to be

approximately 20 percent. Such a high fatality rate would correspond to an even greater casualty rate. Thus, it is likely that most MIA aircraft due to flak damage were also casualty-bearing aircraft. If all MIA flak-damaged aircraft were to be regarded as bearing one or more flak casualties, then there were approximately 781 B–17 flak-damaged casualty-bearing aircraft during June, July, and August 1944. Of this number, 461 aircraft returned and were examined and 320 (41 percent) were not examined (86 returned and not examined and 234 MIA). There were 465 B–24 flak-damaged casualty-bearing aircraft during the same period. Of this number, 172 aircraft returned and were examined and 293 (63 percent) were not examined (112 returned and not examined and 181 MIA). Such proportions of casualty-bearing aircraft, for which observations were not available, would therefore greatly alter the flak-damage data pertaining to both types of aircraft.

Tables 241 and 242 show the densities of flak hits for plane surfaces and fuselages of all the aircraft examined in which there were flak casualties. The aircraft concerned were examined in the same way and by the same personnel who examined all aircraft to which the data in tables 237, 238, 239, and 240 pertain. Figures 300 and 301 show the location of flak hits on casualty-bearing B–17 and B–24 aircraft from which the data in tables 241 and 242 were obtained.

TABLE 241.—*Densities of flak hits on 461 B–17 aircraft in which there were 539 battle casualties*

Surface struck	(1) Area [1] (square feet)	(2) Hits	(3) Number of observed hits [2]	(4) Percent (n) observed hits [2]	(5) Percent (A) expected hits assuming random distribution	(6) Standardized densities $\left(D=\frac{n}{A}\right)$
Plane surfaces only:						
Top	368	236	1. 39	8. 6	16. 7	0. 51
Bottom	368	485	2. 86	17. 6	16. 7	1. 05
Sides	156	215	11. 96 (2. 99)	73. 8	66. 6	1. 11
Total	892	936	16. 21	100. 0	100. 0	
Fuselage only:						
Top	408	288	1. 53	9. 4	16. 7	. 56
Bottom	408	218	1. 16	7. 1	16. 7	. 43
Sides	430	675	13. 60 (3. 40)	83. 5	66. 6	1. 25
Total	1, 246	1, 181	16. 29	100. 0	100. 0	

[1] Projected for "fuselage only."
[2] Data calculated per square foot per 1,000 aircraft.
NOTE.—Figures in parentheses for one side only.

TABLE 242.—*Densities of flak hits on 172 B–24 aircraft in which there were 193 battle casualties*

Surface struck	(1) Area[1] (square feet)	(2) Hits	(3) Number of observed hits[2]	(4) Percent (n) observed hits[2]	(5) Percent (A) expected hits assuming random distribution	(6) Standardized densities $\left(D=\frac{n}{A}\right)$
Plane surfaces only:						
Top	272	65	1. 39	4. 9	16. 7	0. 29
Bottom	272	205	4. 38	15. 5	16. 7	. 93
Sides	194	188	22. 52 (5. 63)	79. 6	66. 6	1. 20
Total	738	458	28. 29	100. 0	100. 0	
Fuselage only:						
Top	270	107	2. 30	8. 0	16. 7	. 48
Bottom	270	73	1. 57	5. 4	16. 7	. 32
Sides	540	580	25. 0 (6. 25)	86. 6	66. 6	1. 30
Total	1, 080	760	28. 87	100. 0	100. 0	

[1] Projected for "fuselage only."
[2] Data calculated per square foot per 1,000 aircraft.
NOTE.—Figures in parentheses for one side only.

Column 3 of table 243 (compare with column 1) shows significant increases in the number of flak hits on plane surfaces of B–17 aircraft. The standardized values given in columns 3 and 1 of table 244, however, show no change in the relative density of hits on vertical surfaces. However, there is an apparent decrease in the ratio of hits on top and bottom surfaces of casualty-bearing B–17's, from 1:3.2 to 1:2.1 (36 percent decrease).

Column 4 of table 243 (compare with column 2) shows even greater increases in the density of flak hits on the fuselages of casualty-bearing B–17's. The standardized values in columns 2 and 4 of table 244 show again no change in the relative density of hits on the sides of the fuselages. However, there is an apparent decrease in the ratio of top to bottom hits from 1:1.8 for the fuselages of all B–17's to 1:0.8 for the fuselages of casualty-bearing B–17's (57 percent decrease).

Column 7 of table 243 (compare with column 5) shows greatly increased densities of flak hits on plane surfaces of casualty-bearing B–24 aircraft. The standardized values for the B–24 in columns 5 and 7 of table 244 show, as in the case of B–17 aircraft, no significant difference in the relative density of hits on vertical (*sides*) surfaces of casualty-bearing aircraft. However, in contrast to a reduced ratio of top to bottom hits on plane surfaces of B–17's, there appears to be an increased ratio of top to bottom hits on plane surfaces of casualty-bearing B–24's from 1:2.3 to 1:3.2 (42 percent increase).

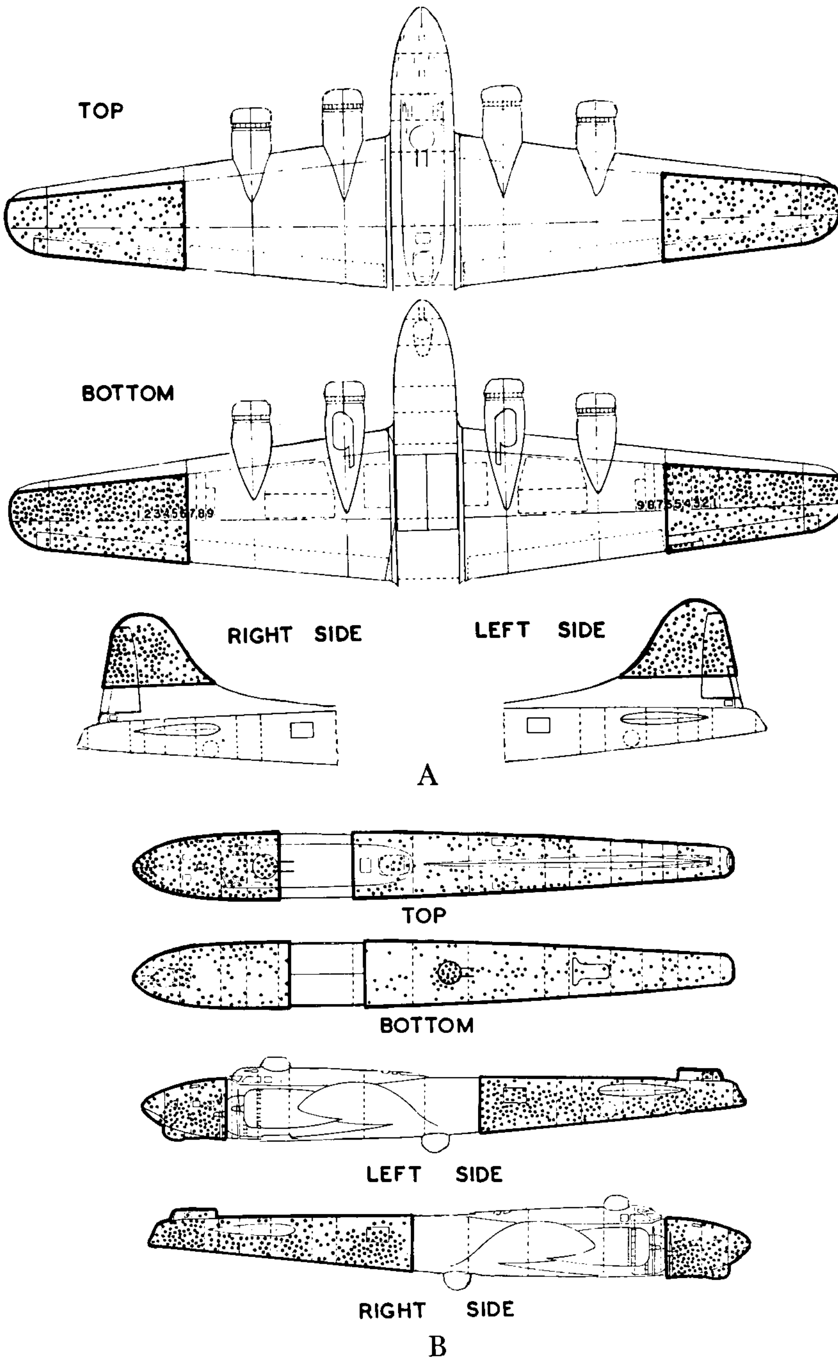

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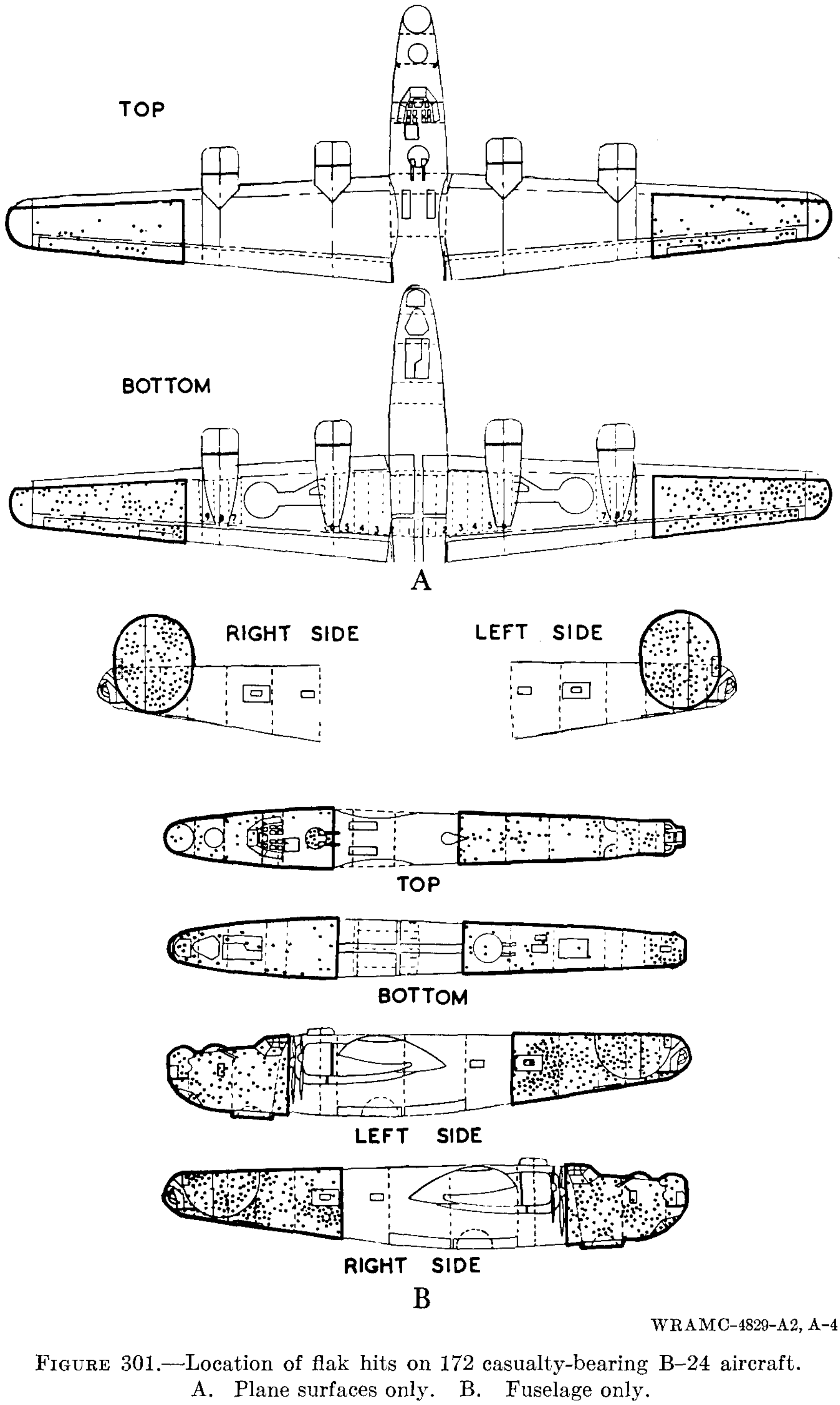
FIGURE 300.—Location of flak hits on 461 casualty-bearing B–17 aircraft. A. Plane surfaces only. B. Fuselage only.



WRAMC-4829-A2, A-4

FIGURE 301.—Location of flak hits on 172 casualty-bearing B–24 aircraft. A. Plane surfaces only. B. Fuselage only.

TABLE 243.—*Résumé of density of flak hits on B–17 and B–24 aircraft*

[Data represent number of hits per square foot per 1,000 aircraft]

Surface struck	(1) Plane surface [1] (total B–17 aircraft)	(2) Fuselage surface [2] (total B–17 aircraft)	(3) Plane surface [3] (casualty-bearing B–24 aircraft)	(4) Fuselage surface [3] (casualty-bearing B–24 aircraft)	(5) Plane surface [1] (total B–24 aircraft)	(6) Fuselage surface [2] (total B–24 aircraft)	(7) Plane surface [4] (casualty-bearing B–24 aircraft)	(8) Fuselage surface [4] (casualty-bearing B–24 aircraft)
Top	0. 45	0. 24	1. 39	1. 53	0. 59	0. 70	1. 39	2. 30
Bottom	1. 43	. 44	2. 86	1. 16	1. 35	. 50	4. 38	1. 57
Sides	5. 16	3. 48	11. 96	13. 60	8. 32	5. 4	22. 52	25. 0
	(1. 29)	(. 87)	(2. 99)	(3. 40)	(2. 08)	(1. 35)	(5. 63)	(6. 25)
Total	7. 04	4. 16	16. 21	16. 29	10. 26	6. 60	28. 29	28. 87

[1] Data are from column 3, table 237.
[2] Data are from column 3, table 240.
[3] Data are from column 3, table 241.
[4] Data are from column 3, table 242.

NOTE.—Figures in parentheses are for one side only.

TABLE 244.—*Résumé of standardized densities for B–17 and B–24 aircraft*

[Data represent number of hits per square foot per 1,000 aircraft]

Surface struck	(1) Plane surface [1] (total B–17 aircraft)	(2) Fuselage surface [2] (total B–17 aircraft)	(3) Plane surface [3] (casualty-bearing B–24 aircraft)	(4) Fuselage surface [3] (casualty-bearing B–24 aircraft)	(5) Plane surface [1] (total B–24 aircraft)	(6) Fuselage surface [2] (total B–24 aircraft)	(7) Plane surface [4] (casualty-bearing B–24 aircraft)	(8) Fuselage surface [4] (casualty-bearing B–24 aircraft)
Top	0. 38	0. 35	0. 51	0. 56	0. 35	0. 63	0. 29	0. 48
Bottom	1. 22	. 63	1. 05	. 43	. 79	. 46	. 93	. 32
Sides	1. 10	1. 26	1. 11	1. 25	1. 22	1. 23	1. 20	1. 30

[1] Data are from column 6, table 237.
[2] Data are from column 6, table 240.
[3] Data are from column 6, table 241.
[4] Data are from column 6, table 242.

Column 8 of table 243 (compare with column 6) shows greatly increased densities of flak hits on the fuselages of casualty-bearing B–24's. The standardized values in columns 6 and 8 of table 244 show a very slight (5 percent) decrease in the relative density of side hits and a slight apparent decrease in the ratio of top to bottom hits on casualty-bearing B–24's from 1:0.7 to 1:0.67 (8 percent decrease).

The analysis of hits on casualty-bearing B–17 aircraft listed in table 241 shows deficiencies of flak hits on the bottom surfaces primarily of the fuselage and secondarily of the planes. These data suggest that MIA B–17 aircraft due to flak damage were lost primarily due to hits on the bottom surfaces of

the fuselage and thus possibly due in part to the occurrence of casualties produced by these hits. The "moth-eaten" appearance in the distribution of hits on the bottom of the fuselages of casualty-bearing B–17's, shown in figure 300B in the regions carrying personnel and parts vital to the aircraft's safe return, further supports this possibility. Hits on the ball turret, a combat position relatively unimportant as far as the integrity of the aircraft is concerned, appear to be distributed normally.

The analysis of hits on casualty-bearing B–24 aircraft listed in table 242 shows deficiencies of flak hits primarily on the top surfaces of planes and secondarily on the sides and bottom of the fuselages. These data suggest that MIA B–24 aircraft due to flak damage were lost primarily because of hits on the top surfaces of planes and only secondarily because of hits on the sides and bottom of their fuselages. Figure 301B also shows a somewhat moth-eaten appearance in the distribution of flak hits on the bottom of the fuselages. However, the disturbed distribution of hits observed on casualty-bearing B–24's suggests that MIA aircraft of that type, due to flak, were more likely lost because of damage to mechanical parts rather than to the production of casualties.

Directional Fragmentation Density of Flak That Caused Casualties

If a man were suspended in the atmosphere in which flak shells were bursting, unprotected by armor or any part of an aircraft, he would be exposed to a distribution of flak fragments as shown in figure 298A if he were at the altitude at which B–17's operate or, as shown in figure 298B, if he were at the altitude at which B–24's operate. However, since a man is in a heavy bomber, he is protected in varying degrees by different parts of the aircraft, by its armament, by the proximity of other men in the aircraft, and usually by body armor either worn or placed in various positions about his aircrew station. The observations made from an analysis of the directional fragmentation density of flak that had caused casualties would differ from those made from an analysis of hits on the outer surfaces of aircraft since many of the fragments flying in space would first strike the exterior of the aircraft, some object within, or body armor and be stopped, thus preventing a casualty from occurring. In other words, the flak fragments that caused casualties would appear to be most reduced in density in the directions from which the man had the best protection and most increased in density in the directions from which he had the least protection. If the unobserved hits on MIA casualty-bearing flak-damaged aircraft would materially affect the observations made on casualty-bearing B–17's and B–24's, then the unobserved hits causing casualties among MIA personnel would be likely to have an even greater effect on the observations made on flak casualties sustained in the two types of aircraft.

It was possible to determine the direction traveled by the flak fragments that caused 545 casualties in B–17's and 215 casualties in B–24's. The location of flak hits on the battle damage reports for the aircraft in which the casualty occurred, the location of the wounds on the casualty, the direction of the wound

track, and the wounds of entrance and exit were all taken into account to determine in which of four "directional zones" the flak fragment which caused each wound traveled. The four directions that were arbitrarily chosen were 45° zones with respect to the equatorial plane. All wounds that were caused by fragments traveling vertically downward or in a downward direction deviating not more than 45° from the vertical were grouped in the 0°–45° zone. Wounds caused by fragments traveling downward in the zone between the horizontal and 45° below the horizontal were grouped in the 45°–90° zone. Wounds caused by fragments traveling upward in the zone between the horizontal and 45° above the horizontal were grouped in the 90°–135° zone. Wounds caused by fragments traveling vertically upward or in an upward direction deviating not more than 45° from the vertical were grouped in the 135°–180° zone. Wounds that could not definitely be placed in one of these four zones were not included in the analysis. Tables 245 and 246 show the grouping of wounds or "hits," by zones, sustained by the casualties in the two types of aircraft.

The standardized densities of hits causing casualties given in column 6 of tables 245 and 246 were obtained by correcting for the varying projected areas of the body (column 1 of the tables). The projected area of a man viewed at an angle of 0° is taken to be 2.3 $(1+0.9 \sin \theta)$ square feet. This formula, though approximate, agrees with the observed projected area sufficiently well for this purpose. The way in which the projected surface area of the body varies with the angle at which it is viewed is demonstrated in figure 302. Viewed from directly above or below, the area is approximately 2.30 square feet,

TABLE 245.—*Directional fragmentation densities of flak that caused 545 casualties in B–17 aircraft*

Direction (θ)	(1) Body area (square feet)	(2) Hits	(3) Number of observed hits [1]	(4) Percent (n) observed hits [1]	(5) Percent (A) expected hits assuming random distribution	(6) Standardized densities $\left(D=\frac{n}{A}\right)$
Degree:						
0–45	3. 31	78	4. 32	12. 0	16. 7	0. 72
45–90	16. 72	225	9. 88 (2. 47)	27. 45	33. 3	. 82
90–135	16. 72	309	13. 56 (3. 39)	37. 71	33. 3	1. 13
135–180	3. 31	148	8. 20	22. 8	16. 7	1. 37
Total	40. 06	760	35. 96	100. 0	100. 0	

[1] Data calculated per square foot per 100 casualties.

NOTE.—Figures in parentheses for one side of body surface only.

TABLE 246.—*Directional fragmentation densities of flak that caused 215 casualties in B-24 aircraft*

Direction (θ)	(1) Body area (square feet)	(2) Hits	(3) Number of observed hits [1]	(4) Percent (n) observed hits [1]	(5) Percent (A) expected hits assuming random distribution	(6) Standardized densities $\left(D=\frac{n}{A}\right)$
Degree:						
0–45	3.31	43	6.04	16.8	16.7	1.01
45–90	16.72	96	10.68 (2.67)	29.8	33.3	.89
90–135	16.72	103	11.44 (2.86)	31.9	33.3	.96
135–180	3.31	55	7.73	21.5	16.7	1.29
Total	40.06	297	35.89	100.0	100.0	

[1] Data calculated per square foot per 100 casualties.

NOTE.—Figures in parentheses for one side of body surface only.

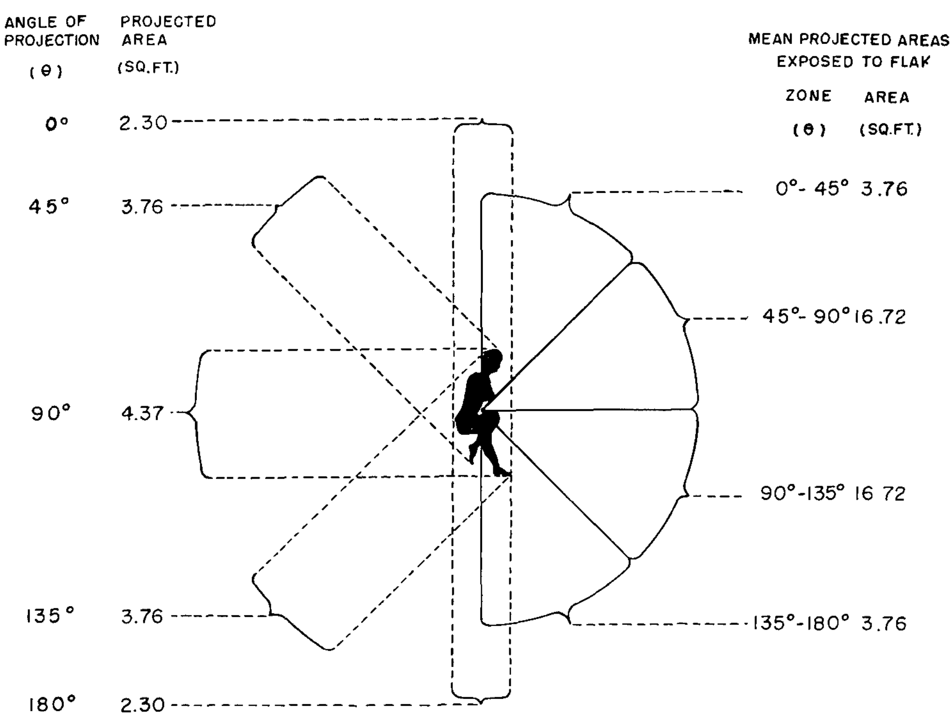


FIGURE 302.—Projected body surface areas.

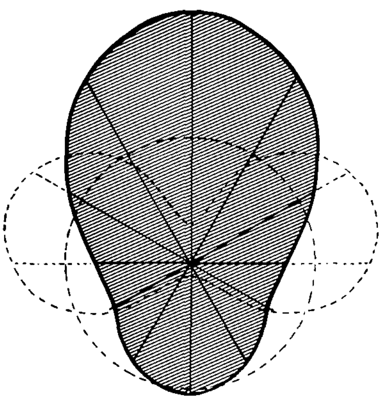
whereas, from any direction horizontally, the area is approximately 4.37 square feet. At an angle of say 45° above or below the horizontal, the projected area of the body is approximately 3.76 square feet.

It is seen that over two-thirds of the casualties were caused by flak fragments proceeding roughly horizontally. The standardized directional fragmentation density of fragments causing this large proportion of casualties however (column 6, tables 245 and 246) was at a minimum, particularly in the case of B–24 casualties. Figure 302 shows that a man viewed horizontally presents an area nearly twice as large as a man viewed vertically. Also, the frequency with which the larger surface area is presented is greatest in the horizontal direction and decreases as the more vertical directions are approached. Thus, the largest proportion of casualties were caused by fragments proceeding, in general, in the direction in which the greatest density of fragments occurred. The apparent decrease in density of fragments that caused casualties by proceeding horizontally however is due to the factor of "protection" to personnel from horizontally dispersed fragments.

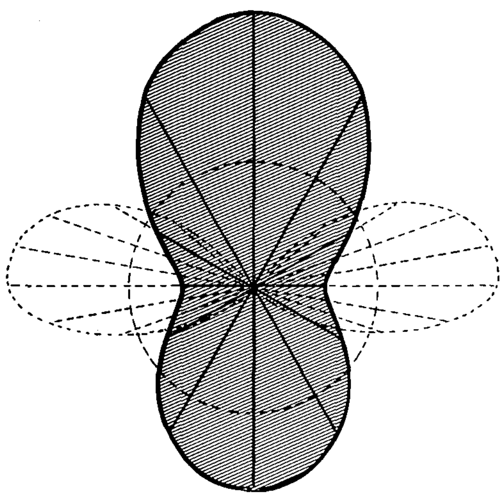
From the figures for the hits on casualties (column 2, tables 245 and 246), a curve of the form

$$r(\theta)=a+b\cos\theta+c\cos^2\theta+d\cos^3\theta$$

can be fitted to give the directional fragmentation densities of fragments that caused the casualties. These curves together with the curves representing the directional fragmentation densities on the aircraft (indicated dotted) are shown in figure 303 to show the relationship between hits on aircraft and hits that



A



B

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FIGURE 303.—Directional fragmentation density. A. Composite flak burst, constructed from 760 flak hits sustained by 545 casualties in B–17 aircraft. B. Composite flak burst, constructed from 297 flak hits sustained by 215 casualties in B–24 aircraft.

caused casualties. The standardized density values used for the construction of the curves are shown in tables 247 and 248.

TABLE 247.—*Directional fragmentation densities of flak against personnel in B–17 aircraft*

Direction (θ)	Standardized Density $r(\theta)$
Degree	
[1] 0	1. 03
30	. 91
60	. 70
[2] 90	. 74
120	1. 16
150	1. 74
[3] 180	2. 01

[1] Vertically downward.
[2] Horizontally.
[3] Vertically upward.

TABLE 248.—*Directional fragmentation densities of flak against personnel in B–24 aircraft*

Direction (θ)	Standardized density $r(\theta)$
Degree	
[1] 0	1. 62
30	1. 37
60	. 83
[2] 90	. 55
120	. 94
150	1. 76
[3] 180	2. 19

[1] Vertically downward.
[2] Horizontally.
[3] Vertically upward.

Figure 303A thus indicates that, while a B–17 aircraft receives the greatest density of hits from a direction 10°–30° above the horizontal with comparatively small density in directions within 45° of the vertical, the casualties suffer the greatest density of hits from below, with lesser density from the sides. Figure 303B, for casualties sustained in B–24's, shows in the same way the lowest density of hits causing casualties proceeding in approximately the same direction from which the greatest density of hits occurred on the aircraft.

GENERAL CONCLUSIONS

With reference to the protective armor in aircraft (p. 585), the significant difference in battle casualty rates in two types of heavy bombers merits special attention. There was one known battle casualty for every 54 B–17's dis-

patched to enemy territory as compared with one for every 80 B–24's dispatched. The relationship between casualties and flak damage to the two types of aircraft may be well expressed by the ratio of casualties to flak hits sustained on the fuselages. For every 100 hits sustained on the fuselages of casualty-bearing aircraft, there were 34 casualties in B–17's as compared with only 19 casualties in B–24's.

It has been learned unofficially that the more difficult and more heavily defended enemy targets were attacked by B–17's and that the targets of lesser importance were usually attacked by B–24's. If this is true and in view of the fact that the rate of planes failing to return from enemy territory was the same for both aircraft (approximately 1 percent), it is possible that the B–24 is more vulnerable to attack by lower burst velocity projectiles. The lower incidence of casualties in proportion to hits in B–24 aircraft may be regarded as a measure of the relative ineffectiveness against personnel of low-velocity flak and the relative effectiveness of low-velocity fragments against B–24 aircraft.

The total projected surface areas of the personnel-bearing portion of both types of aircraft exposed to flak (that is, the fuselage) were approximately the same. The B–24 fuselage presented approximately a 5 percent greater total exposed surface than the fuselage of a B–17. However, the area of an aircraft exposed to highest velocity flak fragments is its bottom surface. The projected bottom surface of the fuselage of a B–17 was 25 percent greater than that of a B–24 (476 square feet for a B–17 as compared with 380 square feet for a B–24). This difference may account in part for the increased vulnerability of B–17 personnel to flak. The "lateral" projected surface of a B–24 fuselage exposed to flak (of relatively lower velocity) was approximately 36 percent greater than the corresponding surface of a B–17.

Aircraft are "lost" or reported missing in action only when the enemy has been successful in crippling a ship to such an extent that it is unable to return to its base. A ship is unable to return to its base if its engines are "knocked out" or if certain vital mechanical parts of the ship are damaged. Also vital to a ship, however, are certain of its crew members or combinations of personnel and mechanical parts of aircraft, and an aircraft might not return to its base if its pilot or copilot should be killed or wounded. Other crew members might not be so vital to a ship's operation, but if these men were killed or wounded it might still influence the ship's chance of returning to its base. Followup studies have shown that the fatality rate in MIA aircrew personnel is approximately 20 percent (1 out of 5) as compared with 1.2 percent for all aircrews that sustained battle casualties and only 0.017 percent (approximately 1 out of 6,000) for aircrew personnel returning from combat missions. The known high fatality rate among MIA personnel implies that there is as well a higher casualty rate in MIA personnel. It is likely that most aircraft that did not return to their bases carried casualties, if not fatal casualties.

By regarding all MIA aircraft as casualty-bearing aircraft, it was found that 1,014 (390 MIA and 624 known to be casualty bearing) B–17's probably carried casualties and that 623 (303 MIA and 320 known to be casualty bearing)

B–24's probably carried casualties. Thus, 2.55 percent of B–17 as compared with 2.08 percent of B–24 aircraft sustained casualties or were missing in action. A chi-square test of the significance of the difference in these values gives $\chi^2=16.35$ (where $n=1$, P less than 0.01). The difference is very clearly significant.

With respect to body armor, the main conclusion reached in the case of B–17 aircraft was that personnel were protected laterally by body armor and neighboring equipment and personnel and that a given weight of armor would provide the best protection from below in addition to, but not instead of, the protection already apparent from horizontally dispersed fragments. In the case of the B–24, a need for protection of personnel from above, as well as from below, was indicated. The B–24 was subjected to the greatest density of hits from just above the horizontal, and vulnerable parts would be best protected from this direction.

CHAPTER XI

Personnel Protective Armor

Maj. James C. Beyer, MC, William F. Enos, M.D., and Col. Robert H. Holmes, MC

The development and field usage of helmets and body armor in warfare before World War II has been adequately documented by a number of excellent books and reports.[1] Most of these references have been utilized in the preparation of this chapter, and in many instances they have provided the sole source of available material.[2]

HELMET DEVELOPMENT

During modern times, the helmet has had a rapid rise in general troop acceptability with remarkably little variation in design. The first protection provided for the head in World War I came about in a purely fortuitous manner. General Adrian of the French Army noted that a soldier who had received a head wound due to a rifle bullet explained his escape from death on the fact that he had carried his metal food bowl under his cloth cap. Therefore, following initial experiments in 1914, steel cap liners ("casque Adrian") were issued to French troops in 1915 and led to the characteristic World War I French helmet in 1916. Many of the other countries soon realized the value of a helmet. The British adopted their own design in 1915; the Germans, in 1915; and the Belgians and Italians, in 1916.

[1] (1) Helmets and Body Armor. Handbook of Ordnance compiled by H. T. Wade. Washington: Government Printing Office, 1919, pp. 413–418. (2) Dean, Bashford: Helmets and Body Armor in Modern Warfare. New Haven: Yale University Press, 1920. (3) Dean, Bashford: Helmets and Body Armor—The Medical Viewpoint. *In* Medical Department of the United States Army in the World War. Surgery. Washington: Government Printing Office, 1925, vol. XI, pp. 1–8. (4) Helmets and Body Armor, Office of the Chief of Ordnance, Washington, 1 June 1945. (5) Gregg, Anne J.: Project Supporting Paper No. 44 Relating to Helmets and Body Armor, 1917—August 1945, Ordnance Department, Washington, D.C. (6) Peterson, H. L.: Body Armor in Civil War. Ordnance 34: 432–433, May–June 1950, (7) Ward, Gordon B.: Personnel Anti-Fragmentation Equipment. Library of Congress, Technical Information Division, Washington, D.C., July 1955. A bibliography, 63 pages.

[2] The members of the Historical Division, Office of the Chief of Ordnance, have been most gracious in locating material in their files and in providing free access to many of the original manuscripts. The illustrations for this chapter were made available through the complete cooperation of Dr. H. C. Thomson, chief of the Historical Branch, Office of the Chief of Ordnance. Much of the material pertaining to helmets can only be written in regard to the history of the development of a particular helmet model, and there is a great lack of medical documentation which really should be the sole purpose of this chapter. Therefore, in many ways, the relating of the development of helmets and personnel body armor would seem to be more of a history of the participation of the Quartermaster Corps and the Ordnance Department rather than the Army Medical Service. However, it is felt that there has been an intimate association and liaison between all of the interested technical services and that the inclusion of this chapter in the present volume follows a natural and logical selection of materials. Full recognition must be offered to the major participation which the Quartermaster Corps and Ordnance Department had in the development of personnel protective armor, and the inclusion of the Medical Service for consultation and advice on development of new prototypes has been gratifying.—J. C. B., W. F. E., and R. H. H.

Following the decision in 1917 to equip the American Expeditionary Forces with a helmet, 400,000 helmets were initially procured through the British Quartermaster's Department. Subsequently, the same type of helmet was manufactured in the United States under the direction of the Ordnance Department, and approximately 2.7 million helmets, M1917, were produced by Armistice day, 1918. The American helmet was a slightly modified version of the British MkI helmet. The helmet was made of 13 percent pressed manganese steel alloy, 0.035 inch thick, and could be ruptured only by a blow of 1,600 pounds or more. The British helmet had twice the ballistic strength of the French helmet. The helmets of British design produced in the United States had an overall ballistic strength 10 percent greater than that of the original British helmet. The ballistics specifications of the M1917 helmet required it to resist penetration by a 230-grain caliber .45 bullet with a velocity of 600 f.p.s. Numerous experimental models were developed to provide (1) additional protective coverage; (2) improved ballistic properties; (3) adaptability for special functions, such as machinegunner, tank operator, aviator, and so forth; (4) a more adequate suspension lining; and (5) a distinctive patriotic design. Because of the large numbers of helmets of the M1917 design which were produced in the United States, none of the experimental models developed by the U.S. Army Ordnance Department received adoption before the end of World War I.

In the interval between World Wars I and II, the United States continued its research and development program on helmets in an attempt to increase the area coverage, to improve the protection ballistics limit (V50 or that velocity level at which there is 50 percent probability of a complete penetration of the test ballistic material by the projectile), and to facilitate troop acceptance by modification of the suspension system. Changes designed to improve the first two factors required careful consideration in order to be compatible with the weight and comfort limitation imposed by other testing technical services. Concurrent with the changes in weapon design were the demands for modification in the helmet specifications. With the advent of new weapons in the hands of belligerent countries, countermeasures can follow several patterns, such as increasing firepower to overcome the advantages of the new weapon, developing specific antitype weapons, or producing interim personnel protective devices.

Between 1918 and 1934, interest and progress in helmet development were maintained by the Ordnance Department and the Infantry Board. Following a series of experimental models (the model 5A was of pot-shaped design and received extensive testing before it was discontinued in 1932) and tests, it was recommended in 1934 that the M1917 helmet with a modified lining of a hair-filled pad be standardized as Helmet, M1917A1 (fig. 304). The final end item with an adjustable headpad weighed 2 pounds and 6 ounces.

A lull in helmet development occurred in the period from 1934 to 1940 when the first draft call was issued. With the resurge of military life and expenditures, new overtures were made to American industrial firms and to

the Metropolitan Museum of Art in New York in an attempt to improve the protective coverage and ballistic limit of the M1917A1 and to take advantage of recent advances in steel alloy manufacture, liner materials, and mass production methods. In addition, a two-piece helmet was considered desirable to meet the increasing variety and complexity of tactical and climatic conditions.

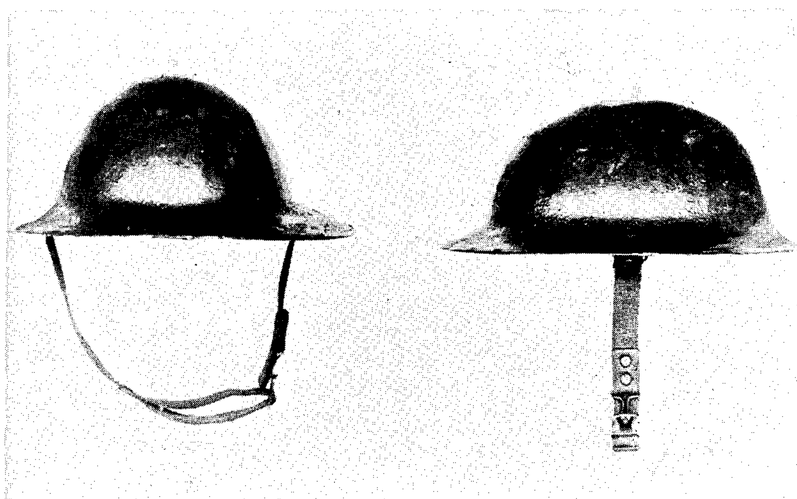

FIGURE 304.—Helmet, M1917A1.

The following quotation from one of the reports of the Infantry Board reveals the natural evolution of the new helmet from the original M1917 design:

> The ideal shaped helmet is one with a dome-shaped top following the full contour of the head and supplying uniform headroom for indentation, extending down the front to cover the forehead without impairing vision and down the sides as far as possible to be compatible with the rifle, etc., and down the back as far as possible without pushing the helmet forward when in a prone position, and with a frontal plate flanged forward as a cap-style visor and the sides and rear flanged outward to deflect rain from the collar opening.

Therefore, the M1917 model was considered suitable for protecting the top of the head and by removing its brim, by adding sidepieces and rearpieces, and by incorporating the suspension system into a separate inner liner, the World War II Army helmet came into being.[3] The original test item was known as the TS3, and it received a favorable report from the Infantry Board in February 1941.

The Army M1 helmet (fig. 305) was standardized on 30 April 1941 and was approved on 9 June 1941. It was of two-piece design with an outer Hadfield steel shell and a separate inner liner containing the suspension system. The complete item weighed approximately 3 pounds, with the outer shell accounting for approximately 2.3 pounds and the inner liner, 0.7 pound.

[3] Studler, R. R.: The New Combat Helmet. Army Ordnance No. 132, 22: 933–934, May–June 1942.

Ballistic protection was afforded only by the Hadfield manganese steel outer shell with the plastic-impregnated fabric liner serving as a light-weight headpiece outside of the frontline area and facilitating the attachment of the suspension system. Various utilitarian functions were also ascribed to the outer steel shell. The ballistics properties of the outer shell had been improved so that it would resist penetration by a 230-grain caliber .45 bullet with a velocity of 800 f.p.s. The Riddell type of suspension (fig. 305C) used in football helmets was modified for the inner liner. The principle of the original Riddell suspension did not contain an adjustable headband, and this feature was developed for the helmet liner. The M1 helmet was a marked improvement

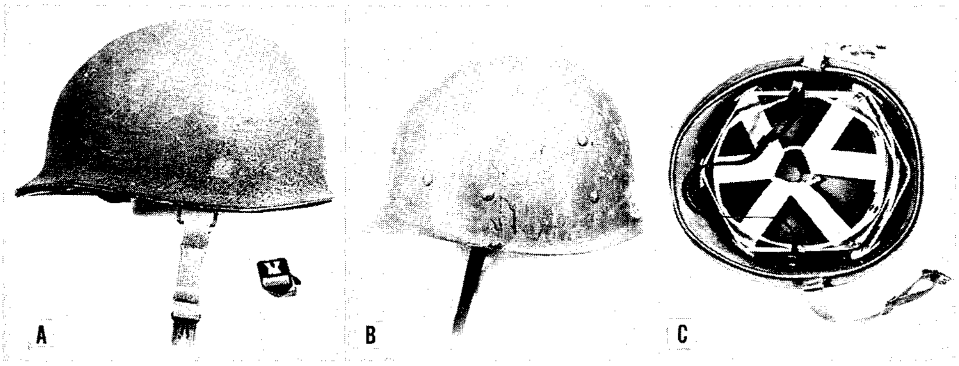

FIGURE 305.—Army M1 helmet. A. Outer steel shell. B. Inner liner. C. Liner with head suspension system and adjustable headband.

over former models (fig. 306) since it furnished increased coverage (fig. 307) over the sides and back of the head and provided a more comfortable fit with the partial elimination of the "rocking" tendency of the older helmets. Following adoption of the M1 helmet, the Ordnance Department retained development and procurement of the outer steel shell and the Quartermaster Department made development and production progress of the inner liner and suspension system.

During the course of the North African campaigns in 1943, the rigid hook fastener of the chinstrap was found to be a source of potential danger by remaining intact under the impact of a blast wave resulting from a nearby detonation and thereby jerking the head sharply and violently with the production of fractures or dislocations of the cervical vertebras. Therefore, it was necessary to redesign the helmet strap with a ball-and-clevis release so that it would remain closed during normal combat activities but would allow for a quick voluntary release or automatic release at pressures considerably below the accepted level of danger. Following extensive tests by ordnance engineers, a new release device was developed which would release at a pull of 15 pounds or more. This device (fig. 308) was standardized in 1944.

SC 118701

FIGURE 306.—Helmet, TS3, later standardized as Helmet, M1 (left), and Helmet, M1917A1 (right), April 1941.

The M1 helmet was the standard item of issue to ground troops, Army and Marine, during World War II and the Korean War. Before the standardization of the M1 helmet, 904,020 M1917A1 helmet bodies were manufactured from January to August 1941. During the period from August 1941 to August 1945, 22,363,015 M1 helmets were produced. Troop acceptability was fairly high, but a common complaint was the lack of stability of the helmet. This problem had its origin, in good part, from the type of ballistic test in practice at the time the helmet was being developed. The caliber .45 pistol ball was the major test weapon, and this type of projectile with its soft lead core and thin gliding-metal jacket will deform easily against the Hadfield steel. When the helmet causes the defeat of this missile at service-weapon velocities, it will be deeply indented, and it was deemed necessary to allow a 1-inch offset

SC 122394, 122408

FIGURE 307.—M1 helmet. A. Front view, illustrating offset and area coverage. B. Side view, showing increased coverage to sides and back of head.

between the helmet and the head. However, battle casualty survey studies during World Wars I and II and the Korean War have shown that the primary wounding agent among the WIA and the KIA casualties was the fragmentation-type weapon. The World War II experiences are universal except for the surveys of some of the Pacific island campaigns where small arms missiles accounted for a greater proportion of casualties. After World War II, fragment simulators in a range of 5 calibers were widely used in ballistics evaluation tests of prospective ballistic materials for helmets and body armor. The advisability or necessity of the present 1-inch helmet offset requires a thorough investigation and evaluation in the development of any new helmet.

A suitable offset will always be necessary to counteract the denting of a metallic helmet or the transient deformation of a nonmetallic helmet, but the prime objective of any protective military headgear is to prevent the entrance of missiles into the cranial cavity. This entrance might be prevented over a

wider range of missile weights and velocities by modification of the present offset concept in helmet design. The missile defeat might result in skull fractures in a number of casualties, but the skull fracture type of injury is amenable to successful treatment by the neurosurgeon.

Despite the widespread use of the M1 helmet by all the U.S. fighting forces during World War II, no definite survey was ever conducted to obtain an accurate evaluation of the value of the helmet. Numerous investigators in

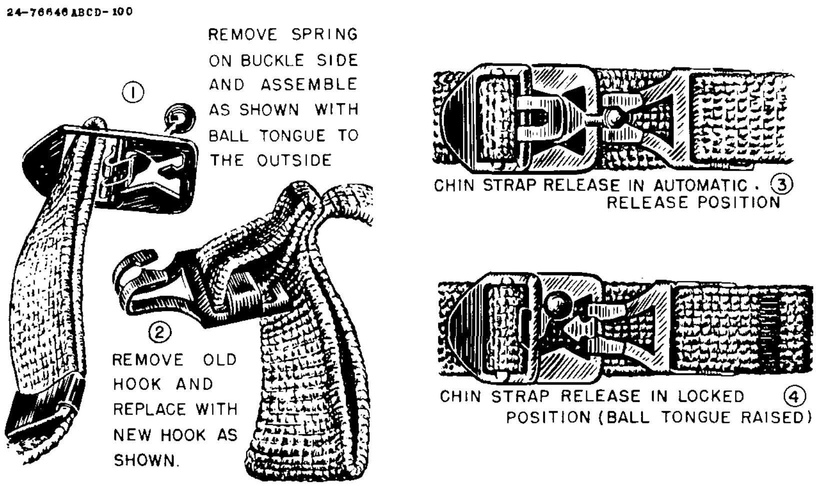

FIGURE 308.—Ball-and-clevis release for chinstrap of M1 helmet.

various surveys and separate publications in medical journals allude to the undoubted value of the M1 helmet in preventing a considerable number of deaths and nonfatal wounds in ground troops. However, because of the marked variability of collection methods and evaluation techniques of the investigators, it is most difficult to derive an accurate correlation based on sound statistical methods.

Some aspects of the value of the M1 helmet are discussed by Beebe and DeBakey in their book on battle casualties.[4] More recently, Norman Hitchman [5] of the Army's Operations Research Office reviewed some of the World War II casualty statistics and reached some important and timely conclusions regarding the value of wearing a helmet in combat. The following observations resulted from this statistical analysis:

1. Of all hits upon the helmet, 54 percent were defeated.

2. For every 100 men wounded while wearing helmets, 9.6 men received wounds in the cranium. Without the helmet, it would be expected that 11.4 men would be wounded in the head.

3. The M1 helmet prevented a number of incapacitating hits equal to 10 percent of the total hits on the body.

[4] Beebe, Gilbert W., and DeBakey, Michael F.: Battle Casualties. Springfield: Charles C Thomas, 1952, p. 176.
[5] Hitchman, N. A.: Keep Your Head . . . Keep Your Helmet. Army 8:42–44, September 1957.

4. The estimated savings in total battle casualties means that the helmet in World War II probably prevented wounds in more than 70,000 men. A significant proportion of these men would have been killed had the helmet not been worn.

5. To get the same amount of saving by protecting other regions, body armor weighing more than twice as much as the helmet would have to be provided.

The numerous casualty surveys conducted during the Korean War provide more accurate anatomic localization of wounds in the head region covered by the helmet as related to the total head, face, and neck region, but again it was not always possible accurately to determine whether the man was wearing a helmet at the time of wounding. One survey was conducted by Capt. George B. Coe, CmlC, in an attempt to determine more accurately the relationship between incidence of head wounds and the wearing of the helmet. One interesting observation was related where men wearing the helmet would assume a prone position to escape missiles from a mortar or an artillery shell and upon striking the ground the helmet would be released from the head and they would sustain a head wound from a second group of shells detonating in the same area.

Accurate information regarding the exact value of the helmet as a protective device is of vital importance in the training and indoctrination of troops. If it can be graphically shown that the helmet is a main line of defense against the greater proportion of projectiles commonly encountered on the battlefield, troop acceptability might be higher. Against the cast iron fragmentation projectiles which were commonly used by the North Korean and Chinese Communist Armies during the Korean War, the M1 helmet probably gave a better performance than with the steel fragments which predominated during the World War II fighting. The relatively soft and brittle character of the cast iron fragments would lend itself to low hardness and toughness and to greater ease of refragmentation and defeat upon impact against the helmet. The U.S. high explosive shell fragment has an average Rockwell "C" hardness of 29–31 and the Soviet cast iron shell fragment has a hardness of 8–14.

Research programs following the Korean War have been directed toward an increase in both the ballistic protection limit and the troop acceptability under varied combat conditions. A multiplicity of factors must be reconciled and coordinated in order efficiently to effect significant changes in either of these properties. World War II investigations proved the efficacy of nonmetallic ballistic materials (nylon and doron) alone or in conjunction with metallic outer shells, but satisfactory field tests were not completed before the termination of hostilities in Korea. With the recent success of these plastics in the body armor developed for ground forces during the Korean fighting, increased emphasis has been given to all forms of research bearing upon helmet development and design.

Notwithstanding the respectable performance of the M1 helmet during World War II and the Korean War, continued improvement should be actively supported. The doldrums of peacetime can prove very lethal to worthwhile

and unspectacular research programs directed toward the development of items of equipment where the present standard items might appear acceptable. Any new helmet, regardless of its V50 superiority, will have to pass the ultimate test of combat troop acceptance, and this is primarily dependent upon the fit and stability of the helmet. The frontline combatant must be indoctrinated and impressed with the protective integrity and necessity of the helmet and equally with the ease and comfort with which it can be worn. Therefore, this is one field of military design where correct tailoring should be obtained commensurate with the imposed limits of the protective ballistic materials. Certain testing procedures on newer experimental helmets would appear to have been excessively delayed, and active aggressive interest in the problem has frequently dropped to a very low level.

HELMET DESIGN

Ground Troop Models

In addition to the M1 helmet, a variety of other designs were developed by the Ordnance Department during World War II. These will be discussed in the paragraphs to follow.

Helmet, steel, M1C (Parachutist's).—This helmet (fig. 309) included a modification of the M1 liner (Liner, Helmet, M1, Parachutist's) with a special chinstrap which insured that the helmet would stay on during the opening shock and descent of the parachute. This liner chinstrap was provided with a chin cup, and two snap fasteners secured the steel shell to corresponding fasteners on the inside of the liner and prevented the separation of the two components during parachute jumping. The regular helmet shell chinstrap was worn behind the head. This item was standardized in January 1945, and 392,000 helmets were produced during the period from January to April 1943.

Helmet, T14 series (Signal Corps).—This was an experimental series of helmets designed to provide the combat Signal Corps photographer with maximum protection under extreme operating conditions. The standard M1 helmet restricted necessary movement and adjustments of still and motion picture cameras and prompted the dangerous habit of removing the helmet while being exposed to enemy fire. In May 1944, the Signal Corps proposed that the front segment of the M1 helmet be cut away and an adjustable, hinged visor flap be placed over the cutaway area. The Ordnance Department prepared test models which did not gain wide acceptance during field tests in the European theater. One objection was due to the fact that, when the visor was locked in its upright position, the helmet bore a superficial resemblance to the German helmet. The Metropolitan Museum of Art incorporated this problem in their work on a helmet for the Armed Forces and developed several promising models. Cessation of hostilities in 1945 prevented the completion of an end item.

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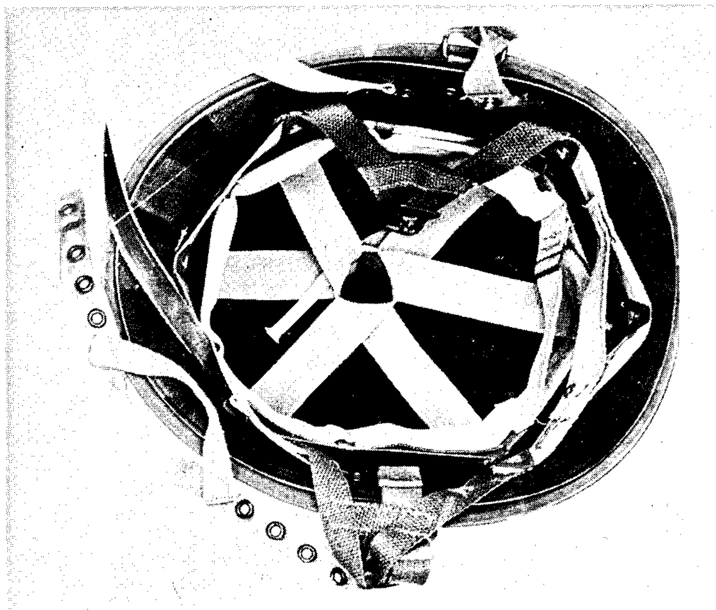

FIGURE 309.—Helmet, Steel, M1C (Parachutist's).

Helmets, T19 and T20 series (Tank).—In November 1940, Headquarters, Armored Force, Fort Knox, Ky., requested the cooperation of the Ordnance Department in modifying the then existing tank helmets to make them more compatible with the varied functions and hazards of tank crewmen. Concurrently, the Quartermaster Corps was engaged in a design of a new tank crash helmet which would offer protection from blows to the head. In 1944, subsequent correspondence requested that the tank helmet designs embody (1) a liner, incorporating a crash-type suspension, over which could be fitted a modified M1 ballistic shell and (2) the ballistic steel shell with an integral crash-type suspension. The proposed military characteristics required that the helmet would (1) protect the wearer from blows to the head during maneuvers over rough grounds, (2) be relatively light in weight with a comfortable fit, (3) permit full access to and the usage of various sighting devices, (4) permit wearing of radio headsets, (5) allow the forehead of the wearer to rest directly against the tank headrest, and (6) be capable of furnishing either ballistic or crash (bump) protection.

The Ordnance Department developed six experimental series, and the Metropolitan Museum of Art evaluated the models in accordance with the Armed Forces specifications. Series T8 incorporated a ballistic helmet with a crash suspension and T9 provided a ballistic cover for the existing tank crash models (fig. 310). During this same period (1944), extensive work had resulted in a number of prototypes of flyer's helmets, and certain of these were considered as being adaptable to the needs of the combat tank crewmen. The T10 series

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FIGURE 310.—Tank crash helmets in use in November 1941.

(fig. 311A) was very similar to the helmet, T9, but provided an associated crash suspension in the steel shell. Helmet, T12 (fig. 311B) was based directly on the Helmet, M3 (Flyer's) with an internal crash suspension, and T13 (fig. 311C) was prepared without the latter feature and was designed to fit over a cut down M1 liner. The T16 (fig. 311D) series was a modified M3 flyer's helmet with a reduction in certain dimensions to bring it within the limitations of the requisite military characteristics.

Between October and December 1944, helmets of the T10, T12, T13, and T16 series were tested by the Armored Force Board, Fort Knox, Ky. All the samples were found to be excessive in weight and overall dimensions and incompatible with the operation of the various sighting devices. The extensive offset and posterior extension of the helmets were developed to accommodate the radio headset and to provide adequate neck protection, respectively.

In 1944 and 1945, a coordinated effort of the Ordnance Department and the Quartermaster Corps was directed toward the development of an acceptable modification of the M1 helmet shell to be used with the crash suspension-type M1 liner. Helmet, T19E1 (fig. 312) was derived from an M1 helmet shell. Changes in its contour permitted the use of various optical equipment while allowing the helmet to be used in conjunction with the new quartermaster

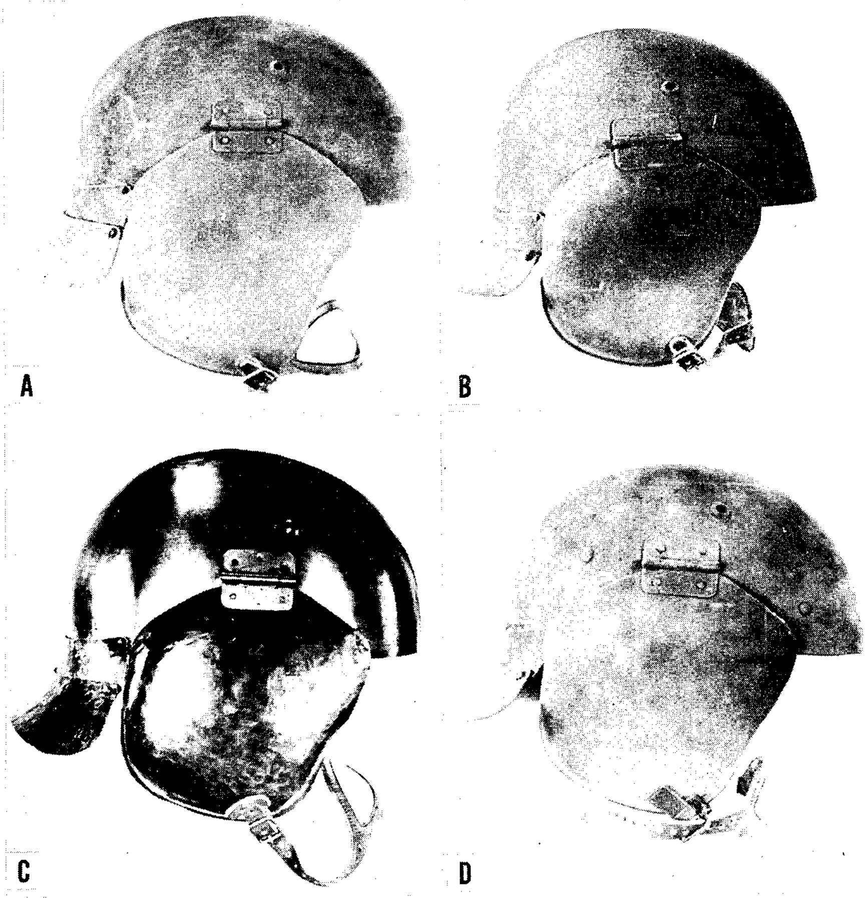

FIGURE 311.—Series of helmets. A. T10. B. T12. C. T13. D. T16.

liner which offered bump protection and clearance for the headsets. An unfavorable report on this helmet was rendered in May 1945 because of the instability of the helmet-liner combination.

After this work on the T19E1 helmet, helmets T20 and T20E1, produced in sample lots, incorporated a head suspension directly within the T19E1 ballistic shell. Finally, the T19E2 and T20E2 series evolved and were based upon a new contour design developed at the Armored Medical Research Laboratory. Definitive reports on these four items were not available before the cessation of hostilities in World War II. However, the consensus was to the effect that further attempts to produce a helmet for use in tanks by modifications of the standard M1 helmet should be abandoned and that the search should be directed toward a completely new and specific tank helmet design. More recent advances in the design of helmets for crewmen of combat vehicles

FIGURE 312.—Helmet, T19E1.

have made increasing use of nonmetallic ballistic materials and have attempted to provide a headgear with high user acceptability and possessing primary bump protection and secondary ballistic protection. Figure 313 illustrates the present combat vehicle crewman's helmet. The following information on this helmet was released on 25 February 1958 by the Public Information Division, Office of the Chief of Information and Education, Department of the Army:

Tank crewmen will have the first helmet specifically designed for their protection when mass protection tests of a new helmet developed by the U.S. Army Quartermaster Corps are completed. Up to the present time, tank soldiers have worn either the standard M-1 Steel Helmet with liner or football helmets, none of which met their requirements. The new helmet, officially designated Combat Vehicle Crewman's (CVC) Helmet, is constructed of multi-layers of laminated nylon fabric, and has a built-in communications system developed by the U.S. Army Signal Corps. The total assembly weighs about three pounds. Nylon employed in its construction is similar to that of the Army's armor vest. Mounted outside the helmet, the communications equipment includes a microphone on an adjustable boom, a three-way switch for listening or talking by radio or through the tank's intercommunications system, and a cable with a quick-disconnect plug for emergency evacuation from the vehicle. Inside the helmet, snug-fitting earphones reduce outside noise and help guard the ears against injury.

Helmets, T21–24 (ground troops).—Throughout the World War II period, investigative work continued in an attempt to improve the standard M1 helmet. In conjunction with the Ordnance Department and the Aero Medical Labora-

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FIGURE 313.—Combat vehicle crewman's helmet, February 1958.

tory, at Wright Field, Ohio, the Metropolitan Museum of Art designed the T21, T22, and T23 series.

The T21 (fig. 314) was patterned after the crown of Helmet, M5 (Flyer's), but without the earflaps and with a brim contour based on the M1 shell. Its shape had been established through anthropometric studies of the human head (fig. 315) and provided a curvature in all directions at all points on the body of the helmet. This latter feature was purported to provide a decrease in the size of the helmet with no sacrifice in area coverage while increasing the strength and protection beyond previously possible limits. The shell weighed 2 pounds and 2 ounces and was to be worn with the conventional inner plastic liner.

Helmet T22 was smaller than T21, was a one-piece unit incorporating a head suspension, and was designed to be worn without a liner. Conversely, the T23 was larger in size than the T21 and permitted the use of thicker liners. In the interim between 1945 and the outbreak of the Korean War, modifications of the series just mentioned and additional new series were developed but none obtained approval or standardization.

Shortly after the adoption of the M1 helmet, various investigations revealed that other materials might possess superior ballistic protective limits

FIGURE 314.—Ground troop helmet, T21.

and that these materials might obviate certain metallurgical and production difficulties inherent in the Hadfield manganese steel. In 1942, a one-piece helmet was fabricated from the resin-impregnated glass fiber laminate known as doron (p. 682). At this time, doron was under consideration primarily for use in a proposed nonmetallic helmet for civil defense workers, but subsequent tests by interested military agencies showed that existing prototypes did not stand up well when exposed to the rigors of combat life.

Aluminum and nylon in combination had received extensive ballistic testing in the development of body armor for ground troops and flyers, and by 1945 samples of helmets utilizing these materials were being produced. Coupled with the high degree of protection against fragmentation-type weapons was the additional possibility of furnishing equivalent coverage to the M1 helmet with an appreciable reduction in weight. Therefore, the T24 helmet was produced consisting of an outer aluminum shell, modeled after the M1, with an inner laminated-nylon liner. Despite the cessation of World War II hostilities, the helmets were tested and deficiencies noted in the ability of the nylon insert to resist delamination and warpage. The T21E utilized the aluminum and nylon elements but was based upon the contour pattern of the T21. This pattern had evolved from scientific anthropometric studies of the human head and permitted a lower silhouette and closer fit than the M1 design. At the present time (1958), the Helmet, M1, is still the standard item of issue to Army ground troops.

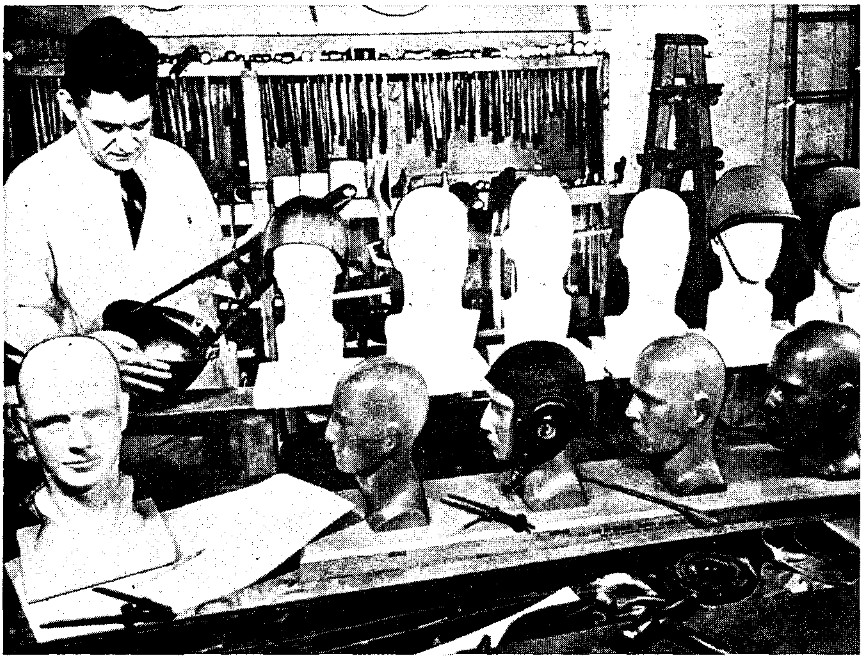

FIGURE 315.—Aero Medical Laboratory standard head models.

Flyer's Models (World War II)

Despite the fact that the development of protective devices for air forces combat personnel in World War II is somewhat beyond the scope of this volume, it is believed that a brief discussion of the development of some of the helmet models is very appropriate since many of the problems which were encountered were very similar to those seen in the development of certain forms for ground force personnel. The complete story of the development of protective devices for air force personnel has been written by Link and Coleman.[6] This work should be consulted by all those who are interested in the medical participation in the development of helmets and body armor in the Army Air Forces in World War II.

By 1943, it had become very apparent that the standard Army helmet required redesigning to make it adaptable to the needs of air forces combat personnel.[7] Similar in nature but more extensive in scope, the problem

[6] Link, Mae M., and Coleman, Hubert A.: Medical Support of Army Air Forces in World War II. Washington: U.S. Government Printing Office, 1955, pp. 617–635.

[7] In 1943, Col. Loyal Davis, MC, senior consultant in neurological surgery in the Office of the Chief Surgeon, European Theater of Operations, U.S. Army, found that the regular issue steel helmet furnished excellent protection against craniocerebral injuries for the soldier but that it did not provide the same excellent protection for crews of aircraft. He realized the necessity for a helmet designed specifically for air force combat personnel. For an account of his efforts to obtain a helmet, designed for this personnel, which would allow free and unrestricted movements, would not interfere in any way with the field of vision, would be lightweight and afford protection from heat and cold, and, most important, would provide protection, at least equal to that afforded by the regular issue steel helmet, against craniocerebral injuries, see chapter IV in "Medical Department, United States Army, Surgery in World War II. Surgical Consultants. Volume II." [In preparation.] See also Davis, L.: A Helmet for Protection Against Craniocerebral Injuries. Surg. Gynec. & Obst. 79: 89–91, July 1944.—J. C. B.

paralleled the work performed for the Armored Forces. Combat airmen were faced with the situation of wearing oxygen masks and goggles and earphones but still requiring some ballistic protective device for the head. Before an acceptable helmet was available, 35.7 percent of unarmored bomber combat crews sustained lethal wounds in the head region. After introduction of the "Grow helmet" or M4 helmet, this number was substantially reduced. A few of the helmet models which were developed and standarized are discussed in the paragraphs which follow.

Helmet, steel, T2 (Flyer's), standardized as Helmet, M3.—This was a direct modification of the M1 steel helmet shell with an associated adjustable head suspension and cutaway on each side of the helmet body to accommodate earphones. A hinged earplate provided protection over the cutaway earphone area. Because of the immediate need for a flyer's helmet, the T2 received extended service tests and was eventually standardized in December 1943 as

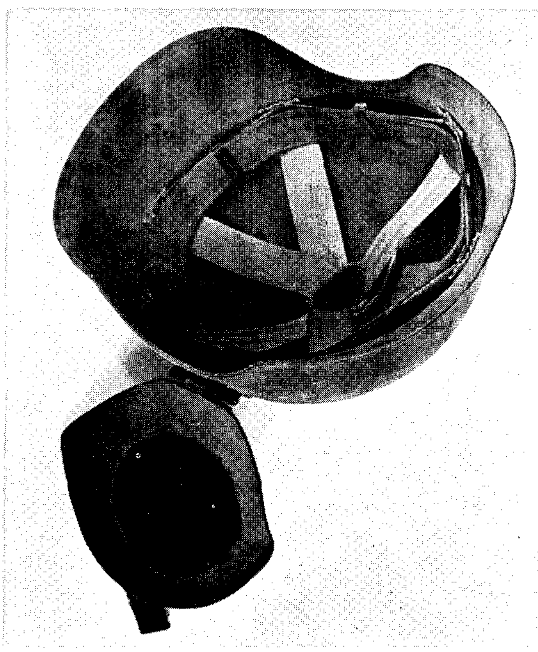

FIGURE 316.—Flyer's Helmet, M3.

Helmet, M3 (fig. 316). This helmet weighed 3 pounds and 3 ounces. Between December 1943 and April 1945, 213,543 helmets of this type were produced. During its development, it was recognized that this type of helmet was unsuitable for a number of confined combat stations where a closely fitting skullcap type of helmet was necessary.

Helmet, steel, T3 (Flyer's), standardized as Helmet, M4.—During the early part of 1943, the Eighth Air Force had combat tested a skullcap type of helmet, and the Ordnance Department proceeded to develop prototypes based

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upon this design and field experience. By September 1943, this model was being tested in conjunction with the T2 model. It consisted of overlapping Hadfield steel plates which were enclosed in cloth pockets and mounted in the skullcap cover of fabric and leather. Openings were available on the lateral aspect of the helmet to permit the wearing of headphones. Notwithstanding the decreased protective coverage of this helmet, it could be worn in the restricted space of aircraft turrets where a larger one would not be acceptable. This helmet was standardized as Helmet, M4, in December 1943 (fig. 317A). It weighed 2 pounds and 1 ounce. In February 1944, it was recommended that the length of the M4 be increased to provide an adequate fit over all types of summer and winter leather flying helmets.

Helmet, T3E3 (Flyer's), standardized as Helmet, M4A1.—Shortly after the M4 became standard issue, it was apparent that armored earplates were required, and a number of experimental models were developed and tested. Finally, by April 1943, the T3E3 was adopted to replace the M4 and was standardized as the M4A1 (fig. 317B). It differed from the M4 by having a slight increase in length and by being equipped with attached metal earplates over the temporal regions. This helmet weighed 2 pounds and 12 ounces. A method was also devised to equip the existing M4 helmets with a fitted hood containing metal earplates. In addition, the M4A1 was later modified (M4A2) to improve the attachment of the earplates and to increase its compatibility with other flying gear. After the adoption of the newer model, a considerable number of experimental helmets were developed and tested in a continuing effort to produce a universal air force helmet with extended area coverage, increased protective ballistics limits, wearer acceptability, and compatibility with associated flying goggles and headphones. Because of fabrication difficulties with the overlapping steel plates in M4 helmet series, emphasis was centered upon a one-piece closely fitting helmet bowl with attached earplates. In addition to the Hadfield manganese steel, a number of other metallic materials were considered, and at one time aluminum seemed to provide the promising combination of comparable ballistic protection at a somewhat lower weight. However, during World War II, Hadfield steel continued to be the principal ballistic material for helmets.

Helmet, steel, T8 (Flyer's), standardized as Helmet, M5.—The helmet, T6E4, had a single steel bowl with no associated suspension system, fitted close to the head, and had large hinged earflaps. It was a most promising model, and future modifications originated from the T6 series. The T8 models were based upon the specifications of the T6E4 but incorporated numerous design changes which increased its acceptability over previous models. The helmet consisted of a one-piece steel bowl with a head suspension system and hinged earplates or cheekplates which extended down on to the sides of the face in line with the leather flyer's helmet. The usual webbing suspension system was augmented by a nape strap that held the front of the helmet against the forehead so that there would be no interference with vision. The cheekplates permitted the wearing of earphones and goggles. One additional mod-

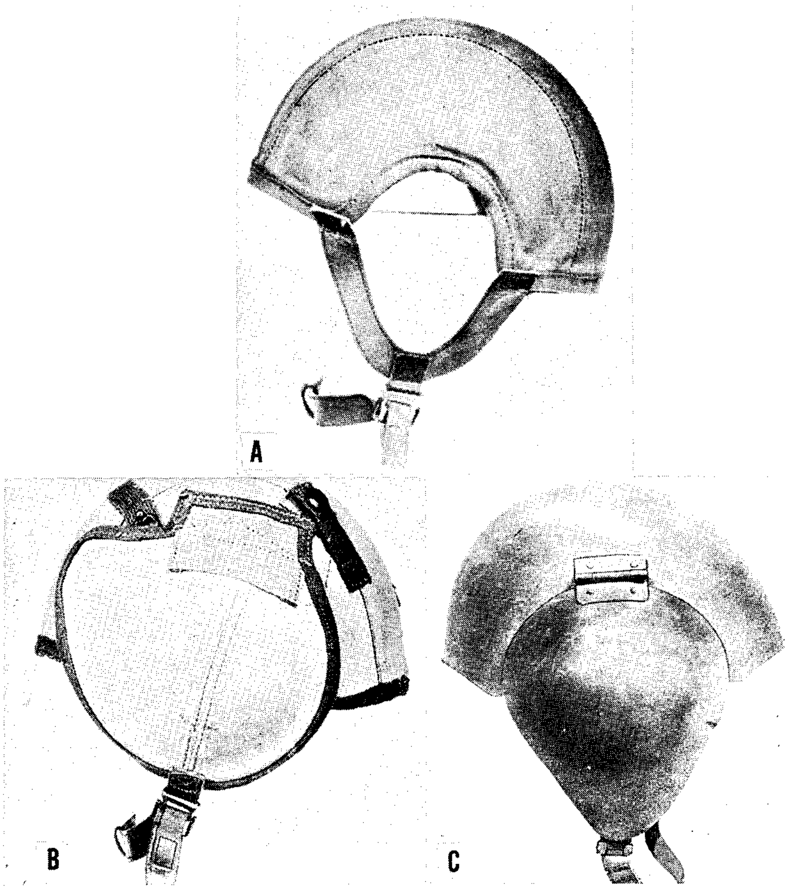

FIGURE 317.—Flyer's helmets. A. M4. B. M4A1. C. M5.

ification provided a slight roll to the back of the helmet to reduce the possibility of injury to the neck region during crashlandings. In January 1945, the T8 was standardized as Helmet, M5 (fig. 317C), and was designated for all combat aircraft positions except the upper turret gunner of the A–20 and the ringsight gunner of the B–29. The M4A2 was still used in the two positions just mentioned. The M5 helmet weighed 2 pounds and 12 ounces. Between February and August 1945, 93,495 helmets of this type were produced.

During the period from October 1943 to July 1944, numerous designs for face armor were studied concurrently with the development of flyers' helmets. Most of the models were intended to be worn in conjunction with the helmet and were to provide protection over the lower part of the face, the neck, and the oxygen mask. Both metallic (fig. 318) and nonmetallic materials were tested. The project was suspended in 1944 because of the lack of specific requirement for this type of armor.

FIGURE 318.—Face armor (T6 type) designed to be worn in conjunction with the flyer's helmet.

BODY ARMOR

"Body armor is not new." [8] Some form of personnel protective device has probably been used in every war which has been recorded in the pages of history.

During the Civil War,[9] a number of types of protective shields and breastplates were developed by interested parties, and some of these were considered for possible official military usage. However, no standard official form of armor was available, and all forms were purchased by individual soldiers. Two types have been described as being most popular among Union soldiers. These consisted of the "Soldiers' Bullet Proof Vest" manufactured by the G. & D. Cook & Company of New Haven, Conn., and the second most popular

[8] I have used this simple statement as the introductory remark in numerous lectures given on the subject of the history of body armor, and it certainly expresses the course of body armor development in modern times.—W. F. E.

[9] See footnote 1 (6), p. 641.

type of breastplate was manufactured by the Atwater Armor Company, also of New Haven. Both types consisted of metallic ballistic material made up of a number of steel plates. The product from the Cook & Company consisted of two pieces of steel inserted into pockets in a regular black military vest. The infantry vest weighed 3½ pounds, and another model for cavalry and artillery weighed 6 pounds. The purchase price of a vest for an officer was $7 and for that of a private was $5. The Atwater armor consisted of four large plates of steel held in position on the body by broad metal hooks over the shoulders and a belt around the waist. In addition, smaller pieces could be attached to the bottom of this cuirass. This vest was heavier than the Cook models and cost approximately twice as much. The supply of these finished commercial products was augmented by specimens of armor apparently of individual manufacture by some local blacksmith.

During the course of his investigations, Dr. Bashford Dean of the Metropolitan Museum of Art was able to test the Atwater armorplate and found that it would defeat a jacketed bullet fired from a caliber .45 pistol at a distance of 10 feet. In his short but excellent discussion of body armor in the Civil War, Harold L. Peterson felt that the chief factors in the discontinuance of body armor at that time were the inconvenience due to the extra weight and bulk and the marked ridicule of those individuals who were wearing the armor by their comrades who did not avail themselves of the protection.

Dr. Dean in his "Helmets and Body Armor in Modern Warfare" presents a complete account of the history of body armor during World War I. Most of the participating countries developed various forms of protective devices for the torso and the extremities, but the excessive weight or lack of adequate protection restricted their general use in combat. Some form of body armor was seen on all fronts from 1915 through 1918, but only on experimental basis, and body armor was never in general usage. The most successful use of armor was by sentinels, members of patrols, and stationary machinegun crews. Despite the relative low troop acceptability because of excessive weight, it was generally believed that these forms of personnel armor had great potential value.

General Adrian who was instrumental in developing the French helmet was also interested in a number of other devices, including an abdominal shield, a breastplate, and leg armor. Some of the medical officers investigating the casualties of British forces through the year 1916 indicated that more than three-quarters of the wounded men could have been saved if some form of armor had been worn. This assumption was based upon a study of the type of wounds (penetrating rather than perforating) and the preponderance of causative missiles being derived from fragmentation-type weapons (either shrapnel or shell fragment). Similar statistics were derived from studies of French casualties where it was believed that 60 to 80 percent of all wounds were produced by missiles of low to medium velocity.

Maj. Charles H. Peck, MC, Assistant Director, Surgical Service, American Expeditionary Forces stated: "Wounds caused by missiles of medium and low

velocity constitute about 80 percent of all." Therefore, numerous test models were developed by the Ordnance Department and a few of these did reach the stage of field testing, but no final standardization was ever achieved.

The British were interested not only in metallic but also in nonmetallic ballistic material. They developed a silk-lined necklet which was purported to stop a 230-grain pistol ball at 600 f.p.s. However, the primary materials, extremely difficult to obtain, deteriorated very rapidly under combat conditions and were considered costly ($25). In addition, the British also studied a 6-pound body shield that was approximately 1 inch thick and was made of many layers of linen, cotton, and silk hardened by a resinous material. Certain responsible military authorities were also convinced of the possible potential value of body armor, and in 1917 General Pershing said: "Effort should be continued toward development of a satisfactory form of personal body armor."

In the interim between 1918 and the onset of World War II, experimentation in body armor materials and design was maintained at a very low level. However, in conjunction with its general program of developing and testing ballistic materials, the Ordnance Department was aware of the possibilities of certain materials' being utilized for a protective garment for the individual soldier.

In the fall of 1941, the British Army was producing a model of body armor in preparation for a field test, and samples of this model were furnished to the United States. The armor weighed 2 pounds and 12 ounces and consisted of three plates of 1 mm. thick manganese steel. Two plates were to be worn over the front and one over the back of the body. In addition, the Ordnance Department was considering two other forms of British body armor; namely, the Armorette and the Wisbrod Armored Vest. The Armorette was composed of metal plates embedded in a vulcanized rubber-duck foundation which imparted a high degree of flexibility to the model. The Wisbrod vest utilized cloth-covered steel plates which overlapped to provide protection to the front of the thorax and abdomen. Both of these latter two models had been under consideration since the early part of 1941. The models were studied by various testing boards of the interested technical services, but all reports indicated that any advantages of such armor would be very slight as compared to the overall loss of combat efficiency and to the increase in the soldier's carrying load. Therefore, individual body armor for ground troops seemed to be a military luxury which could not be indulged in during an all-out global conflict, and there was no apparent requirement for a standard item of issue. This latter decision was officially reached in November 1942 and led to some decline in the overall interest and developmental program for body armor for ground troops. But shortly after this, an extensive program was initiated for the development of protective armor for the Air Forces. It is of some interest to note that in April 1943 an endorsement was written to the Army Air Forces by the Army Ordnance Department in which it was felt that body armor for general use by ground troops had been rejected because of the apparent loss of mobility of the troops and that an application might well be considered for

combat Air Forces personnel. It was felt that ballistic protection could be provided either by use of personnel body armor or by use of plates or curtains which might be placed in strategic places within the aircraft.

Air Forces (World War II)

The history of the development and usage of body armor by combat crewmen of the Army Air Forces during World War II is adequately discussed in the publication by Link and Coleman. The development of these items was so intimately connected with various casualty surveys—some of which are reported in this volume—and by research work of the Army Ordnance Department that a brief résumé would be appropriate in this chapter. No attempt will be made to give a complete coverage of all items and the rationale behind their development, but the more important models will be described since many of these bear a very close relation to subsequent development for Army ground troops.

The initial impetus to the development of body armor for the American flyer was due to the research and field testing which the British had performed in an attempt to develop some form of personnel armor for their ground troops operating in North Africa. Subsequent to this, in early October 1942, an analysis of wounds incurred by U.S. Eighth Air Force combat personnel revealed that approximately 70 percent were due to relatively low velocity missiles. In one survey involving 303 casualties and conducted before the adoption of body armor, it was found that flak fragments were responsible for 38 percent of the wounds; 20 mm. cannon shell fragments, 39 percent; machinegun bullets, 15 percent; and secondary missiles, 8 percent. A later survey of 1,293 casualties revealed a similar breakdown of missiles. In addition, it seemed that protection provided to the regions of the chest and abdomen would bring about the highest rate of return in reducing both fatalities (mortality) and total numbers of hits (morbidity).

Therefore, it appeared to Col. (later Brig. Gen.) Malcolm C. Grow, MC, then surgeon of the Eighth Air Force, that some type of body armor might serve to protect aircrew members and save a considerable number of lives among the combat crews. The initial consideration of a ballistic material was based upon previous British experiments which had revealed that a manganese steel plate 1 mm. in thickness would resist penetration of a caliber .303 bullet at a velocity of approximately 1,250 f.p.s. In addition, this material was shatterproof, had high resistance, and was comparatively light in weight. After deciding on this ballistic material, Colonel Grow, in association with the Wilkinson Sword Company, Ltd., of London, formulated plans for a vest made up of overlapping plates of manganese steel. These 2-inch square Hadfield steel plates were secured in pockets and sewed to a backing of flax canvas. Preliminary testing of the armor was so favorable that Lt. Gen. Carl Spaatz, Commanding General, Eighth Air Force, approved the recommendation on 15 October 1942 for the order of 10 suits of armor for experimental testing. Following this,

sufficient armor for crews of 12 B–17's were ordered and received about 1 March 1943. Later, Lt. Gen. Ira C. Eaker who had assumed command of the Eighth Air Force directed that sufficient armor be produced in England to equip all heavy bombers located there and also recommended that armor suits be provided for all heavy bomber units destined for the Eighth Air Force.

The original armor provided complete protection for the anterior and posterior aspects of the thorax. The vest was placed across the shoulder and fastened by closing the dot fasteners over one shoulder. In addition to the vest, a sporran apron section was suspended from the vest by fasteners and provided protection for the abdomen, crotch, and part of the lower extremities. A number of models were made to be worn by various crew members, depending upon their position and function in the aircraft. The pilot and copilot wore a half vest only in the front, and bombardiers, navigators, and gunners wore full vests to secure both front and back protection. A full-width sporran was for men who had to stand during the performance of their combat duty. Other forms were tapered toward the bottom. The full vest weighed 16 pounds; half vest, 7 pounds; full sporran, 6½ pounds; and tapered sporran, 4½ pounds. The armor was made to wear over all other clothing and equipment and eventually was constructed so that the complete suit could be quickly jettisoned (fig. 319) by pulling a ripcord.

Numerous casualty surveys [10] conducted at various times following the introduction of flyer's armor showed a variable reduction in the total wounds incurred and in the number of fatal wounds over the parts of the body protected by armor. Despite the variability expressed by the various surveys, they all showed one thing in common; namely, that flak suits for combat crewmen were a highly successful and valuable adjunct in decreasing the total number of wounds and the number of lethal wounds in the thoracoabdominal region.

Surveys conducted among heavy bomber combat crew members before and after the adoption of body armor showed the following results. The surveys in the period before the use of body armor were conducted from March through September 1943. The period of survey after the use of body armor was from November 1943 to May 1944. During the March through September 1943 period, 137,130 combat crew members went on bombing missions, and 746 casualties resulted with a total of 896 wounds. This gave a casualty rate of 5.44 men wounded and 6.53 wounds per 1,000 crewmen dispatched on missions. This gave a ratio of wounds received compared to crew members on missions of 0.646 percent. In the November 1943 to May 1944 period, 684,350 crewmen went on missions; 1,567 men were casualties, with a total of 1,766 wounds. This gave a casualty rate of 2.29 casualties and 2.58 wounds per 1,000 crewmen on missions. This gave a ratio of wounds received compared to crew members taking off of 0.248 percent. Therefore, there was a reduction of 58 percent in persons wounded and a reduction of 60 percent in total number of wounds sustained per 1,000 crewmen on missions.

[10] Grow, M., and Lyons, R. C.: Body Armor. Air Surgeons Bull. 2:8–10, January 1945.

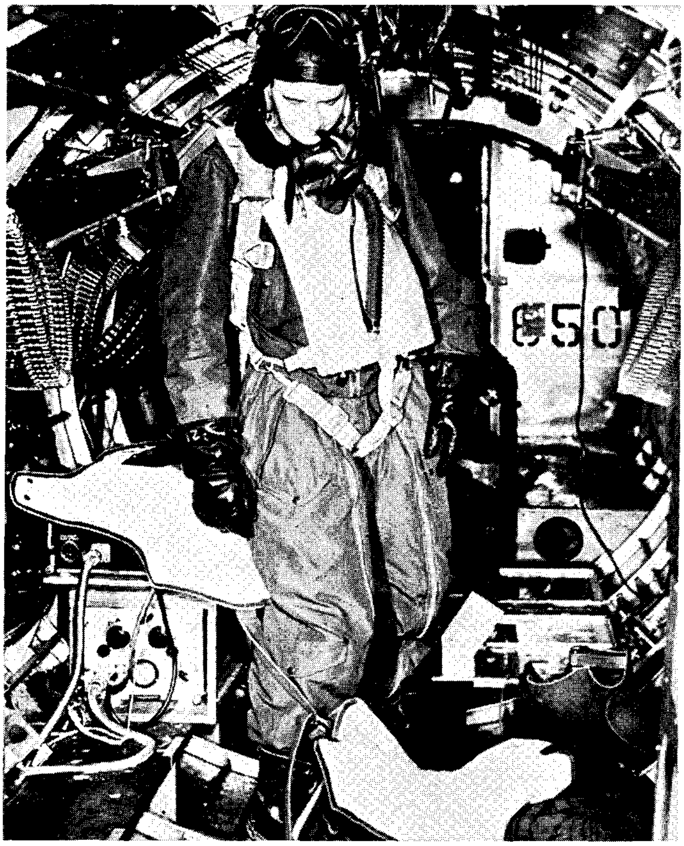

FIGURE 319.—Jettisoning of flyer's armor by means of ripcord and quick-release fasteners.

Since there was the important question of whether the foregoing results were due solely to the usage of body armor or due to a number of tactical conditions, such as change either in combat formations or in enemy tactics, a survey was done of the battle damage to aircraft during the same survey period. In the period before the use of body armor, 26.46 percent of aircraft returning to their bases from bombing missions were found to have battle damage. In the period after the use of body armor, 21.47 percent of returning aircraft had battle damage. Therefore, in a comparison of the two periods, one finds a 60 percent decrease in total number of wounds sustained by crewmen following the introduction of body armor and a concomitant 18 percent decrease in aircraft battle damage. Therefore, some of the reduction in the number of casualties and in the total number of hits sustained by the casualties was undoubtedly due to factors other than body armor, but there can be no doubt whatsoever that the main reduction was due solely to the introduction of body armor.

A study pertaining to the anatomic location of wounds sustained during the two survey periods revealed a reduction of 14 percent in wounds of the head

and neck, 58 percent in wounds of the thorax, and 36 percent in wounds of the abdomen. During the survey period among the heavy bomber combat crew members, there was a reduction in fatality of thoracic wounds from 36 to 8 percent and of abdominal wounds from 39 to 7 percent. This meant that after the introduction of body armor there was a reduction of 77.1 percent in the fatality rate of thoracic wounds and a reduction of 82.8 percent in the fatality of abdominal wounds. During the survey period, it was also shown that body armor prevented approximately 74 percent of wounds in the body region covered. After termination of hostilities in Europe, a comprehensive survey of casualty figures showed that the fatality rate for individuals with thoracic wounds fell from 34.9 percent in the unarmored group to 15.3 percent in the individuals wearing body armor. In those individuals sustaining abdominal wounds, the fatality rate was reduced from 32.5 to 15.7 percent. Therefore, because of the untiring pioneer work of General Grow and his fellow medical officers, the value of body armor for combat crewmen in the Army Air Forces was definitely established, but not until the Korean War was a similar situation attained in regard to combat ground troops.

Initially, the flyer's armor, or flak suit, as it was more commonly known, was produced solely by British manufacturers. However, it soon became apparent that they should not be required to be the sole source of supply for the critically needed manganese steel. Nevertheless, a total of 600 suits were made in England. Samples suits were received in the United States in July 1943, and the Army Ordnance Department took over the task of quantity production and improvement in design. From that date until the termination of World War II hostilities, the Ordnance Department and various civilian institutions were responsible for producing approximately 23 types of flyer's armor. The armor workshop of the Metropolitan Museum of Art became the main design research laboratory in the development of flyer's armor. The Air Force Materiel Command at Wright Field, Ohio, had also been interested in development and production of armor, but this function was also turned over to the Ordnance Department.

The initial production of the armor in the United States was based solely on the design which had been developed by General Grow and his British advisers. Hadfield manganese steel plates, of the same composition as that used in the M1 helmet, provided the ballistic protection. These plates were sewed into cloth pockets and fastened to a cotton-duck backing. However, by the end of 1943, a nylon-duck cloth was substituted for the cotton material. The nylon duck weighed 20 ounces to the square yard and increased the ballistic protection limits of the vest.

The Flyer's Vest, M1 (fig. 320), was a close copy of the design which had been submitted from the Eighth Air Force in England. This was made up of two sections which provided protection for the front and back of the body and was fastened at the shoulders by quick-release dot fasteners. It was intended to be worn by gunners, navigators, bombardiers, and radio operators whose combat duties required them to move about so that they

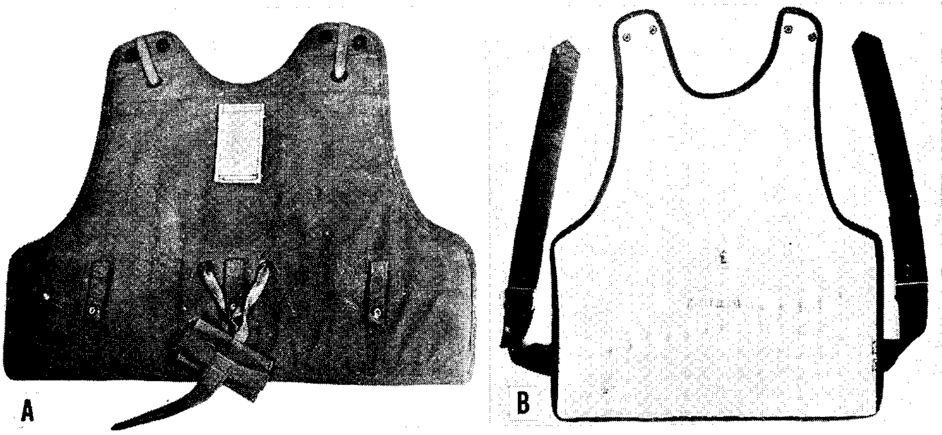

FIGURE 320.—Flyer's Vest, M1. A. Front section. B. Interior of back section.

would be exposed to injury from both the front and the back. The complete M1 vest, including both front (fig. 320A) and back sections (fig. 320B), weighed 17 pounds and 6 ounces and provided an area protection of 3.82 square feet. Between August 1943 and August 1945, 338,780 M1 vests were produced.

The Flyer's Vest, M2 (fig. 321), was made up only of an armored front section, very similar to the frontpiece of the M1 vest, and an unarmored backpiece. It was intended to be worn by pilots and copilots and other combat personnel whose duties would allow them to sit in a seat which could have an armored back and provide the protection for the back of the body. The weight of the front section for the M2 vest was 7 pounds and 15 ounces and provided an area of protection of 1.45 square feet. Between August 1943 and July 1945, 95,919 M2 vests were produced. Both the M1 and M2 vests were standardized on 5 October 1943. As mentioned previously, the ballistic protection was provided by 2-inch square overlapping Hadfield manganese steel plates which were enclosed in pockets, and since the original linen canvas stock for the backing was not available in the United States a cotton canvas stock was utilized and later replaced by ballistic nylon stock.

The Flyer's Apron, M3 (fig. 322A) had a construction similar to the frontpiece of the M1 vest and consisted of a roughly triangular piece of armor intended for use in turrets and other positions in the aircraft where space limitation was a factor. It could be fastened to the front of the M1 or M2 vests by means of dot fasteners and had a total weight of 4 pounds and 14 ounces. It gave an area protection of 1.15 square feet. The Flyer's Apron, M4 (fig. 322B), was similar to the M3 but was larger in size and was intended for use by waist gunners and other individuals who could utilize a full length armor. It had a weight of 7 pounds and 2 ounces and an area protection of 1.66 square feet.

FIGURE 321.—Flyer's Vest, M2. Interior of armored front section.

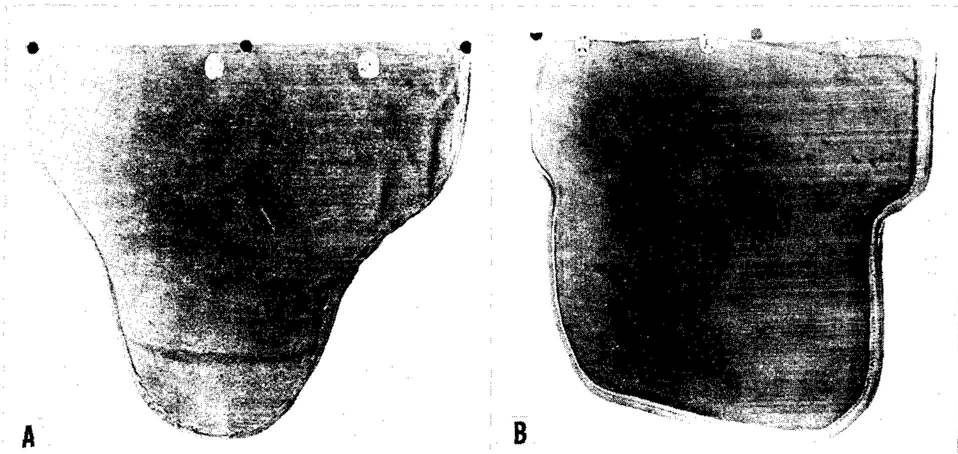

FIGURE 322.—Flyer's apron. A. M3. B. M4.

In addition to the flyer's apron, it was also believed that some protection should be provided to the groin, the abdomen, and the thighs for personnel who remained seated. The first test item was a groin armor, T12 (fig. 323A), designed in 1943. It consisted of 10 steel plates which were shaped and hinged to give protection to the anatomic areas just listed. The armor weighed approximately 8 pounds and gave an area protection of 235 square inches. A later modification known as T13 was received from the Eighth Air Force in January 1944 and consisted of three sections of overlapping steel plates and weighed approximately 14 pounds and gave an area protection similar to that of the T12. The T13 was modified in March 1944 and standardized as Groin Armor, M5 (fig. 323B and C). It was made in three sections so that the central area could be drawn up between the legs. The side section spread out to provide protection for the upper aspect of the thighs.

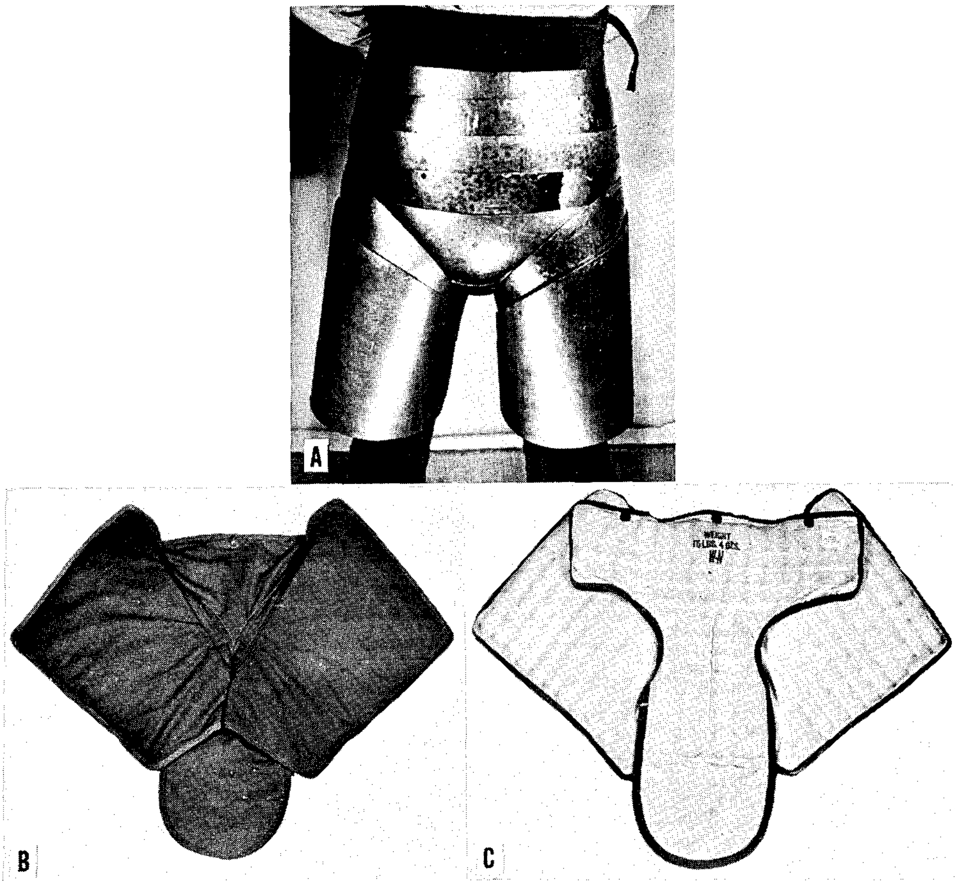

FIGURE 323.—Flyer's groin armor. A. T12. B and C. M5, showing interior view.

The entire piece could be attached to the M2 vest. It weighed 15 pounds and 4 ounces and provided an area protection of 3.72 square feet. All forms of the armor just described were equipped with quick-release dot fasteners and tapes and thongs connected by a ripcord for rapid jettisoning of the armor by the wearer.

The continued research of the Ordnance Department in an attempt to provide an equal or higher level of ballistic protection with an increase in area coverage and a decrease in total weight of the armor soon led to the development of other models utilizing different ballistic materials. The Flyer's Vest, M6 (fig. 324), was standardized on 1 July 1945. This vest had the same function as the M1 vest but was made of aluminum plates with a nylon back padding. The vest weighed 14 pounds and 9 ounces, or 2 pounds and 14 ounces less than the M1 vest, and had an area protection of 4.09 square feet as compared to the 3.82 square feet of the M1 model. The Flyer's Vest, M7, was of the same construction as the M6 and was made to replace the M2 vest. With

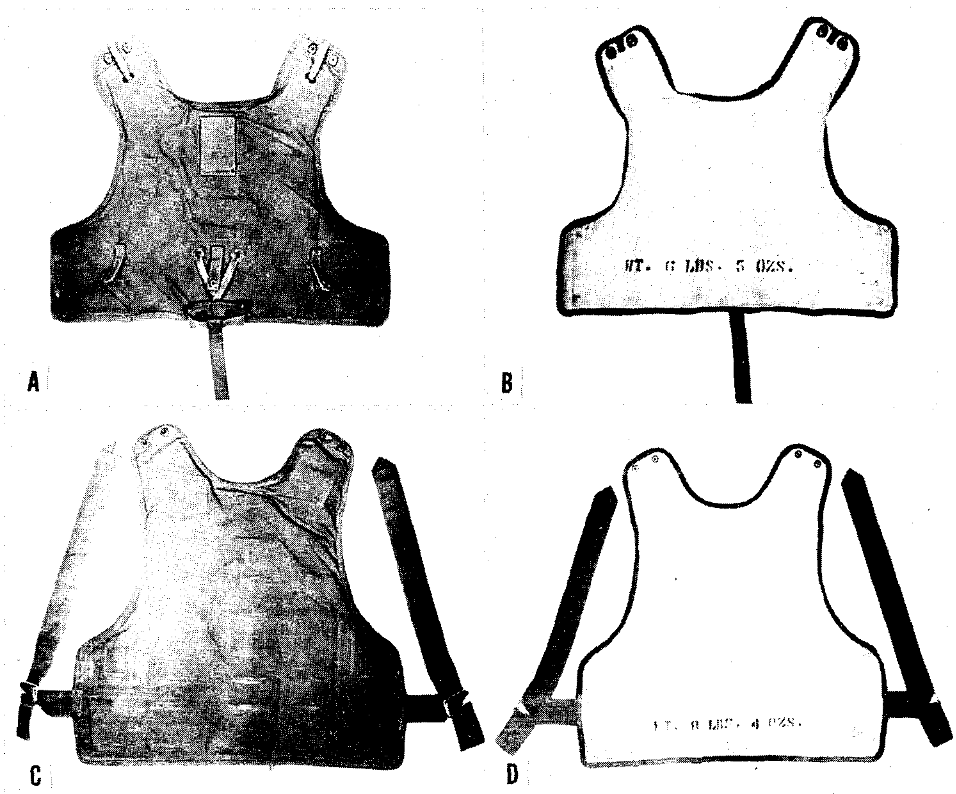

FIGURE 324.—Flyer's Vest, M6. A. Front section, exterior view. B. Front section, interior view. C. Back section, exterior view. D. Back section, interior view.

the shift of emphasis to back-packed parachutes in the Pacific areas, the armor design had to be modified to fit over the parachutes. This gave rise to two models (M6A1 and M7A1) which fulfilled this function. The models were constructed of aluminum and nylon. In addition to these last two items, a number of other experimental models were developed by the Ordnance Department and the Metropolitan Museum of Art. The T5 series of flyer's armor contained larger overlapping armorplates and were held snugly against the body by an elastic webbing. This provided an increase in area protection with a decrease in weight of the end item.

Concurrent with the interest by both the Army and Navy in laminated layers of woven glass fabric impregnated with plastic (doron), this material was considered in flyer's armor. The T37 series in experimental models showed a replacement of the steel plates in the M1 vest by flat doron plates 2 inches square and 0.130 inch thick. A later modification utilized thicker doron plates that had an outer curvature. However, with the advent of improved aluminum and nylon ballistic material, the doron project for flyer's armor was discontinued.

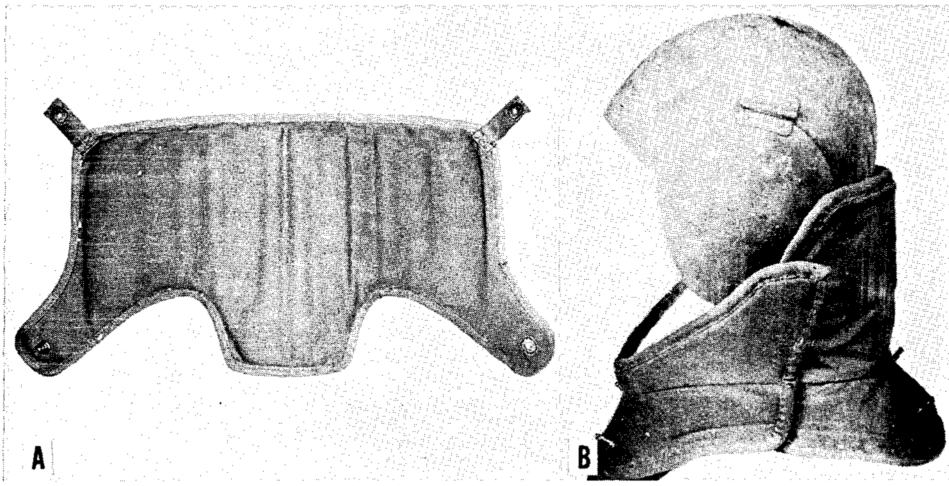

FIGURE 325.—Flyer's neck armor. A. T44. B. T59E1.

In addition to the improvement in the flyer's vest, similar end items and experimental models were developed in aprons and groin armor. The Flyer's Apron Armor, M8 and M9, were standardized in July 1945 and were to be used with the M6 and the M7 vests. Both of these were constructed of aluminum and nylon; the M8 apron armor weighed 4 pounds and 11 ounces while the M9 weighed 6 pounds and 8 ounces. Additional apron armor to correspond with the M6E1 and M7E1 were also developed. With the replacement of the Hadfield steel plates by aluminum and nylon, a similar change occurred in groin armor. The Groin Armor, M10, standardized in July 1945, was made of aluminum and nylon and was to be used in conjunction with the newer vest. At the termination of hostilities, many very interesting tests were being performed to see if flyer's clothing and equipment could be made of nylon-type cloth and by itself provide some ballistic protection. This would then have reduced the weight of the aluminum-nylon-cloth combination ballistic armor and might have provided a higher protection ballistic limit with a decrease in total weight of the armor end item.

At one time, it was felt that protection should be given to the region of the neck which might be exposed between the helmet and the armored vest. Therefore, a T44 series (fig. 325A) of experimental models was developed and consisted of a Queen Anne's type of neckpiece which was made to rest on the shoulders and attached to the M4 series of helmets. This had the same construction as the M1 vest and consisted of 2-inch square Hadfield steel plates. The development of this item was terminated in June 1945 when a shift was made to aluminum and nylon as the ballistic material. The T59 series (fig. 325B) consisted of curved aluminum plates with a nylon-duck backing which was made to fit the contour of the shoulder and neck. Both frontpieces and backpieces were made to be attached to the armored vest of similar construction. One of the experimental models, T59E2, was standardized as M13 in

September 1945. Tables 249 and 250 show some of the production figures for the various types of flyers' armor and a summary of the weight and area protection. All of the statistics have been derived from various sources and might show some variation from other compilations.

TABLE 249.—*Production figures*[1] *for flyers' armor in World War II, 1943–45*

Type of armor	1943	1944	1945	Total
Flyer's Vest:				
M1	111, 842	130, 937	96, 001	338, 780
M2	42, 373	29, 546	24, 000	95, 919
M6			1, 075	1, 075
Flyer's Apron:				
M3	57, 513	54, 571	30, 730	142, 814
M4	68, 467	84, 665	56, 012	209, 144
Flyer's groin armor, M5		41, 872	68, 029	109, 901
Flyer's neck armor:				
T44			10, 969	10, 969
T59E1			100	100

[1] These figures have been compiled from various sources and do not represent final Ordnance Department compilations.

TABLE 250.—*Flyers' armor and corresponding weight and area protection*

Material and type of armor	Weight		Area protection
0.045-inch Hadfield manganese steel:			
Vest:	*Lb.*	*Oz.*	*Square feet*
M1	17	6	3. 82
M2	7	13	1. 45
Apron:			
M3	4	14	1. 15
M4	7	2	1. 66
Groin Armor, M5	15	4	3. 72
0.102-inch 24 ST aluminum and 7-ply 19 ounce nylon duck:			
Vest:			
M6	14	8	4. 09
M7	7	13	1. 82
Apron:			
M8	4	11	1. 23
M9	6	8	1. 89
Groin Armor, M10	13	11	3. 62
0.102-inch 75 ST aluminum and 6-ply 13 ounce nylon duck:			
Vest:			
M6A1	16	15	5. 88
M7A1	7	12	2. 08
Apron:			
M8A1	4	4	1. 23
M9A1	5	12	1. 89
Groin Armor, M10A1	12	5	3. 62
Neck	3	13	1. 33

Following the widespread use and adoption of flyer's armor, a considerable number of other sections of the fighting forces became interested in its possible usage. In October 1943, Motor Torpedo Boat Squadron Number Twenty Five became interested in possible revision or modification of the flyer's armor for their usage. Similarly, the Cavalry Board at Fort Riley, Kans., was also interested in its possible use for mechanized cavalry personnel. In addition, one of the companies producing flyer's armor also submitted samples of a modification of the original design for possible usage in amphibious and other invasion landings. These designs were of various types; some provided only thoracoabdominal protection, and others provided protection for the extremities.

Ground Troops (World War II)

Unlike helmet design, which had a considerable carryover from World War I development and experience, little if any information was available at the advent of World War II on the possible design of a body armor for ground troops. Numerous military authorities had advocated the use of body armor during World War I, but it had only reached a preliminary testing stage before it was generally rejected. During World War I, the United States had developed several types of armor. One, the Brewster Body Shield, was made of chrome nickel steel, weighed 40 pounds, and consisted of a breastplate and a headpiece. This armor would withstand Lewis machinegun bullets at 2,700 f.p.s. but was unduly clumsy and heavy. In addition, the Metropolitan Museum of Art in February 1918 had designed a breastplate based upon certain 15th century armor. Again, this model weighed 27 pounds; all investigators considered it to be very noisy and thought that it markedly restricted all movements of the wearer. Another extremely interesting model was the scaled waistcoats or jazerans which were constructed of overlapping steel scales fixed to a leather lining. The armor was closely fitting and was considered comfortable. The total weight was 11 pounds.

Numerous investigators in the Ordnance Department and in the other technical services had contemplated the development of armor for ground troops in the early stages of World War II. However, very preliminary investigations had shown that most models were too heavy, were incompatible with standard items of equipment, and tended to restrict the mobility of the soldier. Therefore, the development of armor for ground troops was initially rejected as an unsound idea, and the development of a flyer's armor received more or less full attention. However, continued investigation in the development of lighter weight metallic ballistic material and in the relatively new field of nonmetallic ballistic material led to a resurge in interest for armor for ground troops. Therefore, the historical study must be traced through both types of ballistic material, and initially the types of armor utilizing metallic material will be discussed.

It is difficult to ascertain exactly when the redevelopment of armor for ground troops was initiated, but it apparently began sometime near the middle

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FIGURE 326.—Japanese body armor; the type studied by Lt. Col. I. Ridgeway Trimble, MC.

of 1944. In June 1944, the Army Service Forces requested armor for the protection of soldiers from antipersonnel mines. Another major initiating feature was undoubtedly due to some of the excellent work performed by Lt. Col. I. Ridgeway Trimble, MC, then chief of the surgical service at the 118th General Hospital, Sydney, Australia. Colonel Trimble became very interested in reports concerning the use of armor by Japanese ground troops. After a great deal of difficulty and personal disappointment, he was able to secure a copy of Japanese armor (fig. 326). Based on the Japanese design and his own personal observation as to the areas to be protected and the most commonly encountered wounds and causative agents, he developed a model for ground troop armor.[11]

In addition to Colonel Trimble's persistence in presenting his material, various other members of the consulting division of the Medical Department of the Army were very instrumental in overcoming some of the prejudice which was present on the part of the services which would use the body armor.

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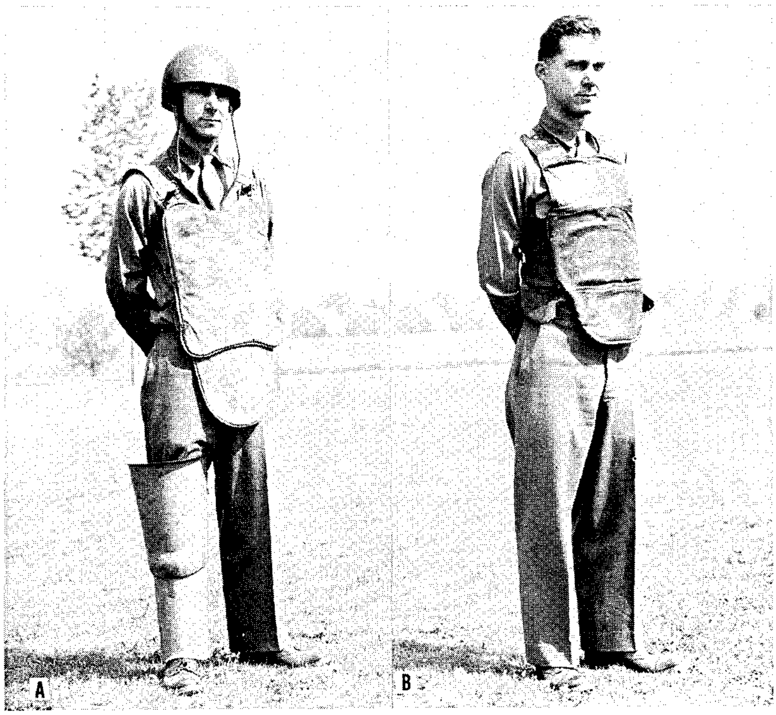
[11] A chronological report of his development of a design for body armor for ground troops has been prepared by Dr. Trimble and is presented on pages 685–689. It is of considerable significance to note the general course the development followed, and it is also of some personal interest to us to see the great many obstacles which had to be surmounted before the responsible individuals developed any great interest and respect for the submitted item. As mentioned by Dr. Trimble, a report of the body armor design and photographs of the Japanese armor were submitted to Dr. George R. Harrison, Chief of the Research Section, General Headquarters, Southwest Pacific Area. The initial report was tendered in April 1944, but owing to the accidental loss of the report and pictures, it was not until 23 May 1944 that the report was finally on its way to Washington. After a review of the material, Dr. Karl T. Compton, Chief, Office of Field Service, Office of Scientific Research and Development, War Department, advised the Commander in Chief, Southwest Pacific Area, that the Ordnance Department was extremely interested in Colonel Trimble's design and felt that it represented an improvement over the one which they were currently considering.—J. C. B., W. F. E., and R. H. H.



OCO–A3751

FIGURE 327.—Japanese body armor. A. Type III. B. Type II.

Other types of Japanese body armor (figs. 327, 328, and 329) which were captured in the Pacific consisted of an anterior thoracoabdominal shield with and without lower extremity protection. Various other members of casualty surveys in the Pacific areas, notably in the New Georgia and Bougainville campaigns, were also convinced of the apparent importance which body armor might have in reducing total number of wounds and number of lethal wounds in ground troops.

Based upon the armor submitted by Colonel Trimble and on the various other specimens collected by technical observers of the Ordnance Department in the Southwest Pacific Area, an experimental model was developed and this design was known as vest, T34. The armor consisted of 0.684-inch thick carbon steel plates. Owing to the excessive weight of the end item and also to the development of lighter weight ballistic materials, the T34 series was discontinued. Various other experimental models were being tested at about the same time and one of these consisted of the armor, breast, T36, which was patterned somewhat after a World War I model. The vest, series T39, consisted of a small piece of anterior armor with a stitched nylon-webb backing and utilized various metallic ballistic materials, such as steel or aluminum, in the form of overlapping plates. Numerous other experimental models were

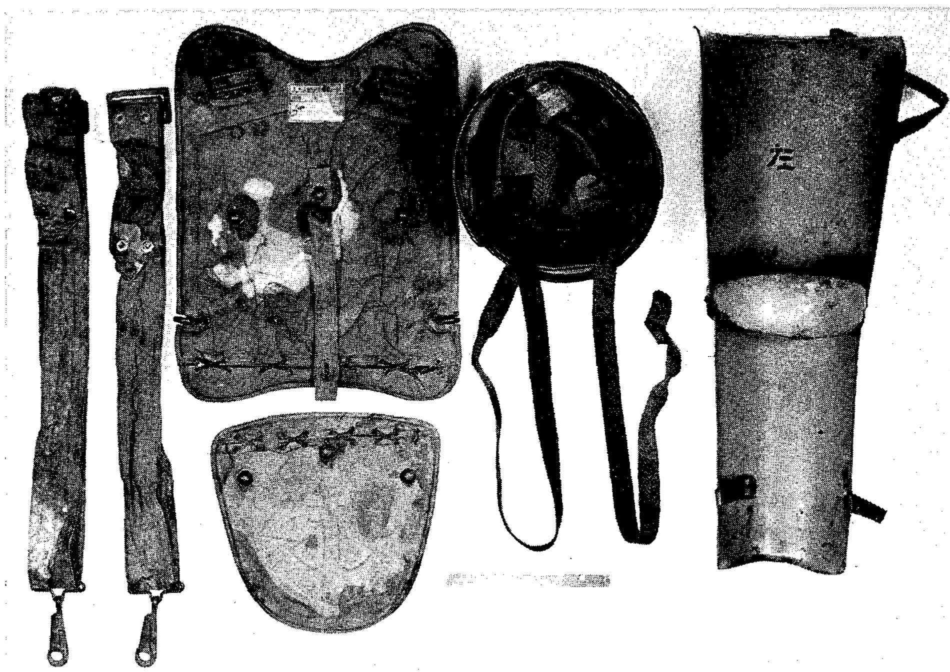


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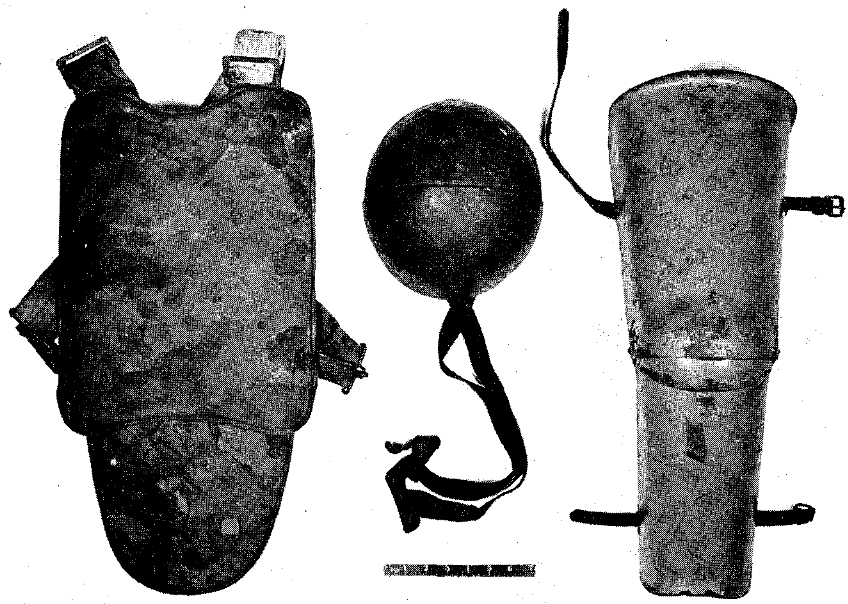
FIGURE 328.—Japanese body armor, Type III, disassembled.

developed, but only those which resulted in a standardized end item will be discussed.

The vest, T62E1, consisted of two pieces, front and back, which were fastened together at the shoulder by quick-release fasteners. The ballistic materials consisted of 0.102-inch thick aluminum plates and a backing of 5-ply nylon cloth. All of the aluminum plates had a slight overlapping to provide thorough protection, and there was a small anterior flap on the frontpiece which was designed to give additional protection to the region of the heart and great vessels. The vest weighed 9 pounds and 10 ounces and had an area protection of 3.45 square feet. The vest, T62E1, was modified in order to provide additional ballistic protection and resulted in the T64 series which was standardized in August 1945 as the Armor, Vest, M12 (fig. 330).

This M12 vest was made of thicker aluminum plates than the T62E1 series and had additional layers of nylon cloth. It weighed 12 pounds and 3 ounces and provided an area protection of 3.45 square feet. The design had been modified to provide greater protection for the anterior portion of the thorax both by increasing the width of the main frontpiece and also by increasing the size of the anterior flap over the heart and great vessels. In addition, some increase in protection was provided for the axillary regions. However, the areas of the junction of the neck and thorax and of the axillary regions were still relatively uncovered and, as it was seen during the use of



OCO-A3789

FIGURE 329.—Japanese body armor, Type III, assembled.

the M12 vest during the Korean War, provided a ready access for the entrance of missiles into the thorax. An Apron, Model T65, was also produced to be attached to the M12 vest in order to provide ballistic protection for the lower part of the abdomen and the groin region. The apron could be attached to the bottom of the vest by quick-release fasteners. It was made of 21-ply nylon cloth, weighed 1 pound and 9 ounces, and had an area protection of 0.66 square feet.

A considerable number of the vests and aprons were produced and were scheduled for field testing and observation by a joint medical-ordnance-infantry team [12] just at the cessation of the war in the Pacific. In July 1945, 1,000 T62E1 vests with the T65 apron and 1,200 T64 vests were shipped to the Pacific theater for field testing, but this was never accomplished. Therefore, the vest received considerable experimental testing, but it was not until the Korean War that it was utilized in the field. With the rebirth of body armor during the Korean War, the M12 vest was used initially by American troops in conjunction with the newer all-nylon-type vest. Following the completion of the initial surveys and standardization of the final end item, all U.S. frontline troops were equipped with the newer all-nylon or doron vests, and the M12 vests were used by Republic of Korea troops.

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[12] Monthly Progress Report, Army Service Forces, War Department, 31 July 1945, Section 7: Health, p. 15.

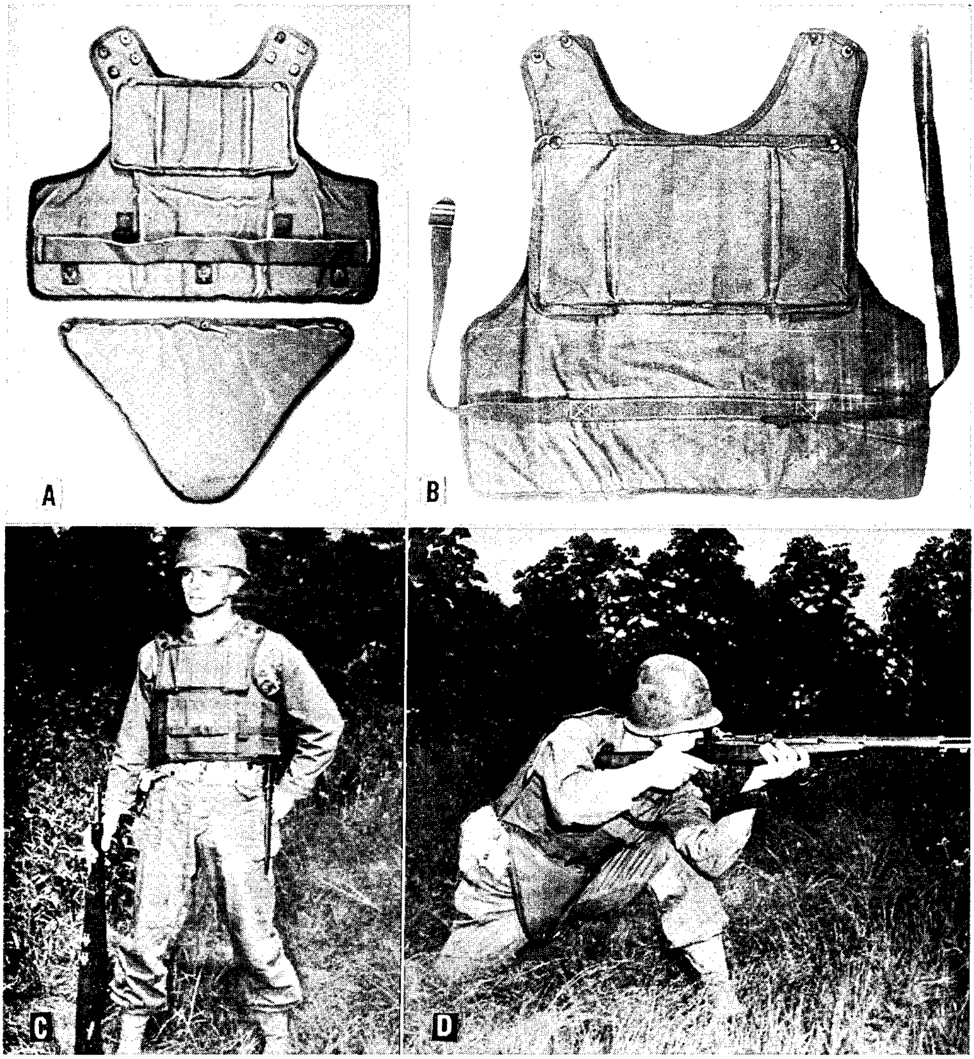

FIGURE 330.—Armor, Vest, M12, for ground troops. A. Front section with apron, T65. B. Back section. C. Front view of M12 vest on soldier. D. Side view of M12 vest and T65 apron, on soldier.

The following tabulation shows some of the production figures for ground-type armor in World War II:

Type of armor:	*Number produced*
Vest:	
T62E1	[1] 4, 100
M12	[2] 53, 352
Apron, T65	[1] 8, 060
Crotch, T16E4	[3] 12, 220
Eye, T45E6 (M14)	[4] 100

[1] For June 1945.
[2] For June, July, and August 1945.
[3] For January–June 1945.
[4] For September 1945.

The production of the M12 vest was slated to continue to a certain degree after August 1945, and before the termination of hostilities it was estimated that 100,000 vests of this model would have been produced by September 1945. Table 251 is a summary of the type of armor and its corresponding weight and area protection.

TABLE 251.—*Ground troop armor and corresponding weight and area protection*

Type of armor	Weight		Area protection
Vest:	*Lb.*	*Oz.*	*Square feet*
T62E1 (0.102-inch 24 ST aluminum plates and 5-ply nylon duck)	9	10	3. 45
M12 (0.125-inch 75 ST aluminum plates and 8-ply 13 oz. nylon duck)	12	3	3. 45
Apron, T65 (21-ply 13 oz. nylon duck)	1	9	. 66
Crotch, T16E4 (manganese steel and nylon)	3	6	1. 15
Eye, M14 (manganese steel)		7	

Following the termination of hostilities in the Mediterranean and European Theaters of Operations, it soon became very evident that some type of protective devices would be required by personnel engaged in minefield clearance. As early as June 1944, the Office of the Chief Engineer was engaged in the development of a protective device for the combat boot. The overall project was later coordinated with the Ordnance Department and led to the development of the T16 series of crotch armor.

The model T16E4 was based on a previous flyer's model and originally consisted of a central crotch section with two overlapping metal plates which were hinged on the sides. Later, the central hourglass-shaped section was developed with two lateral phalanges made up of nylon material. The central area continued to be made of small overlapping metal plates and was fastened by means of straps to the cartridge belt. A later model, the T16E6, provided a reduced area coverage through elimination of the central protection in the

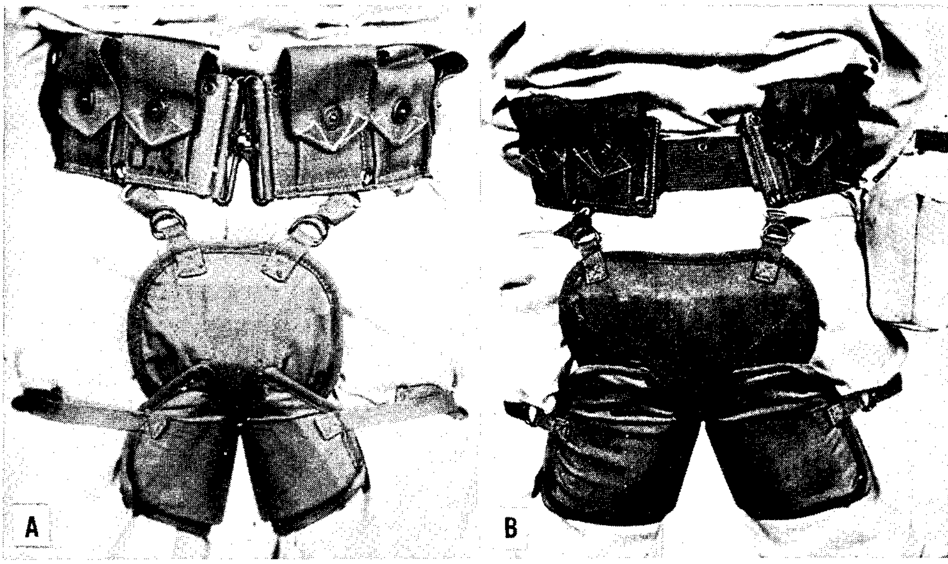

FIGURE 331.—Crotch armor, T16E4. A. Front view. B. Back view.

rear and a reduction in the size of the lateral leg phalanges. However, some increased protection was provided in the region of the groin and genitalia. This model was also constructed of a combination of 2-inch square manganese steel plates and nylon-duck material. It was believed that the crotch armor could be used in conjunction with other items of personnel armor and some locally improvised lower extremity protection for those individuals engaged in mine clearance. The model T16E4 (fig. 331) weighed 3 pounds and 6 ounces and provided an area protection of 1.15 square feet.

There is a dearth of medical statistics in regard to the positive importance of crotch armor for such personnel. However, numerous casualties were seen during the Korean War who suffered extensive saddle-type injuries due to detonation of landmines. It is very conceivable that protection in the region of the groin, the upper part of the thighs, and the buttocks would have been of some value for these individuals. Therefore, in conjunction with the development of the thoracoabdominal vest during the Korean War, an all-nylon crotch armor was produced, but it was not intended for general usage. It was advocated only for personnel engaged in specialized tasks, such as mine clearance.

In May 1945, samples of eye armor were being manufactured by the French Army, and designs to fit the U.S. M1 helmet were collected for testing by the Army Ordnance Department. These models were not considered adequate, and a new series of eye armor, T45 (fig. 332), was developed. This consisted of a plate of manganese steel, the same as that in the M1 helmet, and was provided with small vision slits. The entire structure was mounted in a rubber dust-goggle frame. Close coordination between the Ordnance Department,

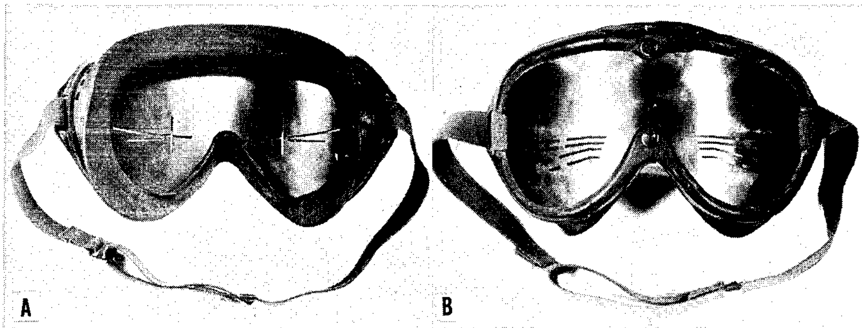

FIGURE 332.—Eye armor, T45 series. A. T45E4. B. T45E6.

Engineer Corps, Army Ground Forces, and the Office of the Surgeon General showed that the T45E6 (fig. 332B) was the most acceptable design, and it was standardized on 10 January 1946. Notwithstanding the cessation of hostilities by this time, it was believed that a standard item was required for the clearance of minefields in occupied countries.

It is of some interest to note that other types of protection for ground troops very similar to that which was tested in World War I also saw some consideration during World War II. An example of this was a project on mobile shields (fig. 333) which was initiated in September 1943. It was considered that the device could be manipulated by a single man and that it would provide protection against rifle and machinegun bullets at a very close range. This would permit the soldier to close in on highly fortified positions and provide protection for soldiers stationed in advanced observation posts. It was believed that the ballistic protection would have to be provided by armorplates of considerable weight and thickness and that the entire device would have to be transported by means of wheels. In order to provide the degree of ballistic protection considered necessary, the planners thought the weight would have to range in the neighborhood of 150 to 200 pounds. After a very brief consideration, the entire project was discontinued.

The use of nonmetallic ballistic material for body armor was a result of close liaison between various developmental agencies in both the Army and Navy and only reached the possibility of a possible end item in the Navy. However, because of the association of the Army Quartermaster Corps and Ordnance Department in its development, some brief mention of it would be appropriate at this time. The search for a nonmetallic ballistic material stemmed partially from a desire to reduce the overall weight of metallic body armor and also because of the critical shortage of the metallic material during World War II. Therefore, an active search was carried out by research and development people in all branches of the military services. Two of the most active sites of research were the Research and Development Branch of the Military Planning Division, Office of the Quartermaster General, and the Naval Research Laboratory. The Quartermaster Corps was interested in

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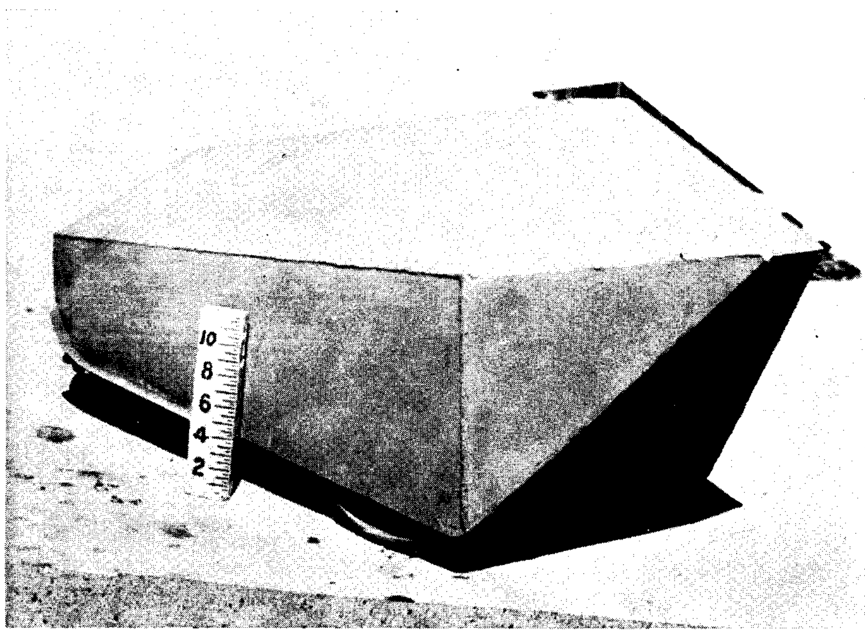

FIGURE 333.—Mobile shield, T1E2.

obtaining a nonmetallic material both for body armor for ground troops and for usage in civilian defense helmets. The Naval Research Laboratory was interested in the possibility of body armor for use by Marine ground forces and certain shipboard personnel. The Army Ordnance Department was also actively engaged in this search and was responsible for all ballistic evaluation tests. Woven glass-fiber fabric impregnated with plastic (doron) had been considered in August 1944 for use in flyers' armor, but the program was discontinued following the favorable test results with aluminum-nylon combinations. The doron was to be utilized in the form of 2-inch square plates, 0.130 inch thick.

A number of industrial concerns instigated active research programs, and in May 1943 the Dow Chemical Company laminated a fibrous glass fabric which immediately proved very promising. The initial product consisted of layers of glass filaments of Fiberglas bonded together with an ethyl cellulose resin under high pressure. Some of the individuals working with Col. (later Brig. Gen.) Georges F. Doriot, then director of the Military Planning Division, Office of the Quartermaster General, decided that the project should be known as the "Doron Project" in his honor. Therefore, the glass fiber laminate manufactured by the Dow Chemical Company became known as and continued to be called doron.

The initial material was known as doron, Type 1, and future modifications consisted primarily of variations in the bonding resin in order to give a more adequate ballistic performance over a wider temperature range. Most of the

body armor developed during World War II utilizing doron was prepared from a form known as doron, Type 2. In addition to the military developmental agencies, numerous private industries were also involved in the research, development, and production of doron material. These included the Westinghouse Electric Corporation, the Continental-Diamond Fibre Company, the United States Rubber Company, the Hercules Powder Company, the American Cyanamid Company, the General Electric Company, The Firestone Tire and Rubber Company, The Formica Company, the Monsanto Chemical Company, and numerous others.[13]

Because of biservice interest in the possible usage of doron, a Joint Army-Navy Plastic Armor Technical Committee was established. This committee included members from the Office of the Army Quartermaster General, the Naval Research Laboratory, the Navy Bureau of Ships, the Office of the Army Chief of Ordnance, the Navy Bureau of Medicine and Surgery, and the Navy Bureau of Aeronautics.[14] The purpose of the committee was to coordinate all research and development efforts and also to facilitate the production of doron. Ballistic research had provided sufficient information so that it was possible to calculate that a ⅒-inch plate of 8-ply doron, Type 2, would have a protection ballistic limit sufficient to stop a caliber .45, 230-grain bullet fired from the standard service automatic pistol at a velocity of 800 f.p.s. Therefore, in order to provide some degree of safety over this calculated minimal V50, it was felt that the material for body armor should be made up of ⅛-inch 15-ply doron, Type 2.[15] The Army Ordnance Department felt that a better correlation could be attained between the use of nylon-aluminum combinations and protection ballistic limit, body coverage, and total weight of the finished item. Therefore, doron was tested in a considerable number of experimental models, but the consensus was that Hadfield steel or aluminum-nylon combinations were superior. Therefore, no end items were developed in the Army program utilizing doron as the ballistic material. However, the Navy felt that doron was a most promising material and continued toward the development of some form of armor for Marine ground troops and shipboard personnel.

The ⅛-inch thick doron plates were utilized by the Navy in two forms; namely, (1) by placing eight panels into pockets on the outside of the Navy kapok lifejacket and (2) by sewing plates on the inside of the pockets of the standard-issue Marine Corps utility jacket. The armor used in both jackets weighed 4 pounds and covered a body area of approximately 3 square feet.

In an attempt to provide a more drastic demonstration of the ballistic properties of doron and also to determine whether the doron armor could be closely applied to the body or would require some offset, a most courageous demonstration was conducted by two Navy officers. Lt. Comdr. Edward L. Corey, USNR, wore the new armored lifejacket vest and permitted an associate, Lt. Comdr. Andrew Paul Webster, USNR, to fire at him with a caliber .45

[13] (1) Fuller, P. C.: Laminated Glass Cloth Used as Body Armor. The Frontier 8:8, December 1945. (2) Fetter, Edmond C.: *Doron Armor*. Chemical and Metallurgical Engineering, February 1946, p. 154.

[14] King, L.: Lightweight Body Armor. Quartermaster Rev. March–April 1953, p. 48.

[15] Webster, A. P.: Development of Body Armor. Hosp. Corps Quarter. 18:31–33, October 1945.

pistol. There was complete defeat of the bullet, and this demonstration was repeated 21 times with no serious injury.

As a result of the total testing procedure, the Marine Corps requested that a full battalion of landing troops be equipped with armored jackets. Approximately 1,000 jackets were prepared and were intended to be used with a Marine division during the Okinawa operation. A survey team from the Naval Research Laboratory and from the Office of the Quartermaster General of the Army were to conduct surveys on both armored and unarmored men in an attempt to ascertain the jacket's actual value and also guide future design in developmental programs. Unfortunately, the Marine division which was to conduct these tests was not employed in the Okinawa operations. A few of the armored jackets were probably used in the last phases of the fighting on Okinawa, but no large-scale survey was conducted.

The development of doron was sufficiently advanced so that armored doron jackets could have been available for the troops at the time of the invasion in Normandy and undoubtedly would have been very instrumental in saving a considerable number of lives. However, there is always a great deal of reluctance and inertia which has to be overcome before the using agencies will accept body armor. This is not meant as a reflection upon the Ground Forces but rather exemplifies their innate and natural desires for a battle to reach a swift and successful conclusion. This can only be accomplished by having the largest number possible of active fighting men who can swiftly and completely perform all combat duties. Therefore, any form of personnel armor has to be completely compatible with all equipment required for the performance of these duties, impose a minimal additional weight load, be comfortable in all climatic conditions, impose little if any restriction on mobility, and finally have a high degree of troop acceptability. If it can be graphically demonstrated that body armor can be constructed so that it will meet all imposed military characteristics, there is a more general acceptance of the item by the Ground Forces.

Naturally, the Medical Corps is immensely interested in any item which brings about a reduction in morbidity and mortality of battlefield casualties. During World War II, medical treatment of the battle casualty had reached a high degree of excellence, and if hostilities had continued it would have soon become apparent that some additional means would have to be provided for the reduction of total number of wounds and number of lethal wounds. In other words, something would have been required forward of the battalion aid station level in an attempt to prevent men from being wounded and to reduce the number of men who were being killed instantly. Unfortunately, this lesson of body armor was not learned until late in World War II, and it was not until the Korean War that the numerous sceptics were convinced and body armor was accepted wholeheartedly.

Let us hope that peacetime stagnation will not completely shackle the developmental program so that in the advent of any future hostility body armor will be available at its immediate onset.

REPORT OF DEVELOPMENT OF A DESIGN FOR BODY ARMOR FOR THE FOOT SOLDIER

On or about 1 September 1942 I read in the Sydney newspapers about an armored Japanese vest captured in New Guinea by Australian soldiers during the Papuan campaign, and consulted Dr. Dew, Professor of Surgery at Sydney University, as to where I might procure such a vest. He wrote to Colonel W. J. Hailes, Medical Directorate, L.H.Q. Victoria Barracks, Melbourne, whose letter of 12 September 1942 told me that work along these lines was being studied in the Middle East by a member of the Medical Research Council of Great Britain. Lt. Colonel R. V. Graham's letter of 16 November 1942 written from the 103rd Australian General Hospital stated that he had asked his son who was in New Guinea at the time to try to procure such a vest for me.

Colonel C. A. Jillet, D.D.O.S. First Australian Army, wrote 30 November 1942 that the First Army had not received such equipment.

Letters written to the Police Departments of the cities of New York, Chicago, Pittsburgh, and Los Angeles resulted in replies during January and February 1943 telling of the protective armor used by them.

19 November 1942 I wrote Brig. General Hanford MacNider asking him to try to procure a vest for me in New Guinea, and asking him for his ideas on protection for foot soldiers.

Colonel C. N. Kellaway, of the Australian Army, and Director of the Walter and Eliza Hall Institute of Research in Pathology and Medicine, personally brought me from Melbourne information relative to work done by the Body Protection Committee of the Medical Research Counsel of Great Britain.

25 November 1942 I called on Colonel C. C. Alexander, Chief of Staff to Maj. General Richard Marshall, Commanding General, SOS, to ask him how to procure a Japanese vest telling him that I had for a long period thought some practical armor protection could be worked out for ground troops. Colonel Alexander was most interested and advised me to see Colonel Carroll, the Chief Surgeon, and Colonel Thorpe of G2. Colonel Carroll was enthusiastic and spoke of his having thought of including the spade of the entrenching tool as body protection. Major Suave in Colonel Thorpe's office promised to obtain the Japanese vest for me.

9 January 1943 a letter came to me from G.H.Q., SWPA., Rear Echelon entitled "Captured Japanese Bullet Proof Vests," which attached a letter from the office of the Director of Staff Duties, L.H.Q., Australian Army, acknowledging my request on 24 November 1942 for the loan of a Japanese Bullet Proof Vest, adding that the only one in the possession of the Australian Army was being tested at the Broken Hill Pty. Steel Works, Newcastle, N.S.P., and suggesting that I inspect the vest at these premises.

17 February 1943 I received a captured Japanese vest (fig. 334) from Commander J. C. Morrow of the Australian destroyer "Arunta" through one of his officers, Midshipman Norman H. Smith. I showed it to Colonel Carroll and Colonel Alexander and on 26 Feb. 1943 had the Signal Corps make drawings and pictures of it.

16 April 1943 the U.S. Quartermaster Department of G4, SOS, asked me to try out some plastic material as possible use in body armor so Major Coleman of that department and I made some firing tests on the shooting range at Long Bay, N.S.W., the plastic material being easily pierced and fragmented by the caliber .45 automatic pistol and Thompson submachinegun bullet.

22 March 1943 Mr. R. M. Service of the Australian Army Inventions Directorate forwarded to me the analysis of the armor plate of the captured Japanese vest and that of some Australian steel submitted by an Australian civilian, a Mr. R. Welch, who was trying to interest the Australian and American armies in a steel jacket made of individual pieces of steel approximately 4 inches square, linked together with a hinge on all four edges. Mr. Welch's armor was put on by inserting one's head through a hole in the center of the gar-

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FIGURE 334.—Lt. Col. I. Ridgeway Trimble, MC, wearing captured Japanese vest.

ment, like putting on a poncho. Beginning at this time, at the request of Mr. Welch and Mr. Service, Lt. Colonel D. Garrison of the U.S. Ordnance and myself tested Mr. Welch's vest on the firing range as well as a model based on the Japanese vest in my possession and made for me by chief operating room nurse, 1st Lt. A. M. Sency. The plates for my vest were six large ones (fig. 335), overlapping and placed inside the vest, in accordance with the Japanese plan (fig. 336). However, my plates were made from plaster casts moulded on a man of 150 lbs, 5 ft. 7 in. in height and covered more of the regions of the collar bones, the upper part of the breast bone, the flanks and the lower abdomen than did the Japanese.

Mr. Welch kindly offered to hammer out for me some steel plates in exact accordance with my plaster casts, and we used these new plates of mine to test on the firing range as well as testing his linked steel armor.

His armor proved entirely unsuitable, because a missile striking a hinged joint would penetrate the armor in the majority of instances.

25 March 1943 I sent to Brig. General C. C. Alexander, Hq. USASOS, APO 501 the first summary of my study on protective body armor, telling of my possession of the Japanese vest and recommending a vest "constructed along the lines of the captured Japanese one" for our own army. This report was forwarded by General Alexander to the Chief Surgeon and the Chief Ordnance Officer, SOS Headquarters, APO 501.

13 June 1943 Brig. General J. L. Holman wrote to me requesting that my set of Japanese armor be sent to the Chief Ordnance Officer in Washington, D.C. through Base Section 3, APO 923. This armor was sent by me 17 June 1943, and acknowledged by General Holman 20 June 1943.

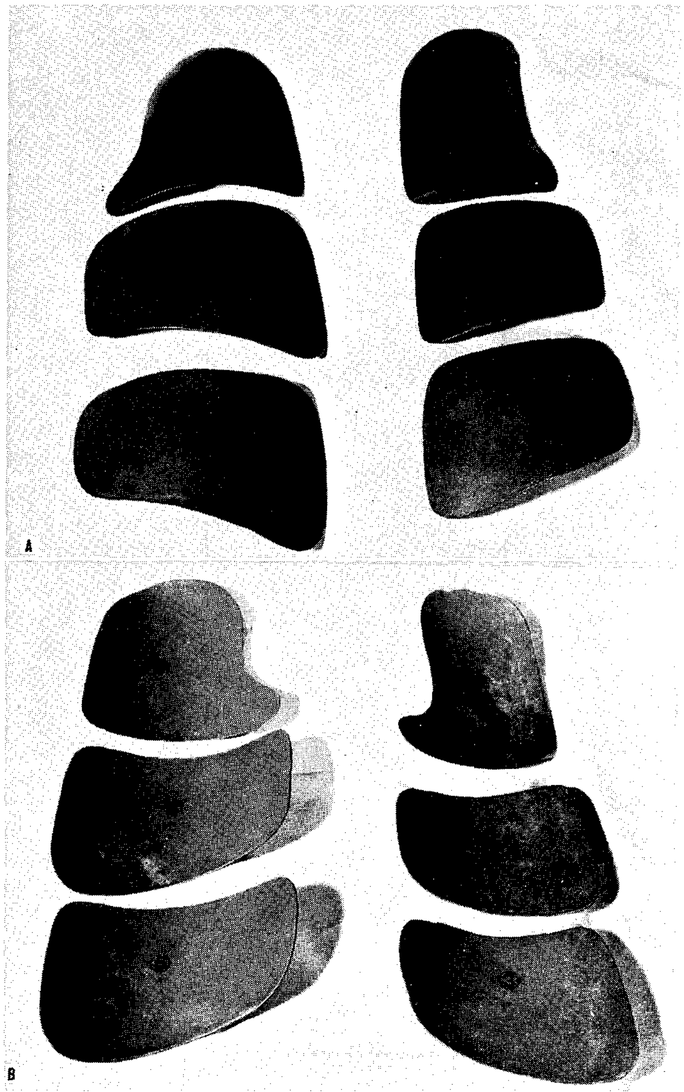

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FIGURE 335.—Armorplates developed by Lt. Col. I. Ridgeway Trimble for incorporation into a proposed armor vest for ground troops. A. Front view. B. Back view.

16 September 1943 I wrote General Holman objecting to a public demonstration of body armor before the press by Mr. R. Welch at Base Section 7. The armor was apparently that of his design since the Sydney newspaper account, dated 15 September 1943, spoke of light steel plates linked together; but the enclosing tunic in the photograph published by the newspaper was similar to my modification of the Japanese one. Mr. Welch's original armor had no tunic. The performance of the vest against various types of firearms was reported in this paper. The demonstration was made without consulting our army or intelligence at any time.

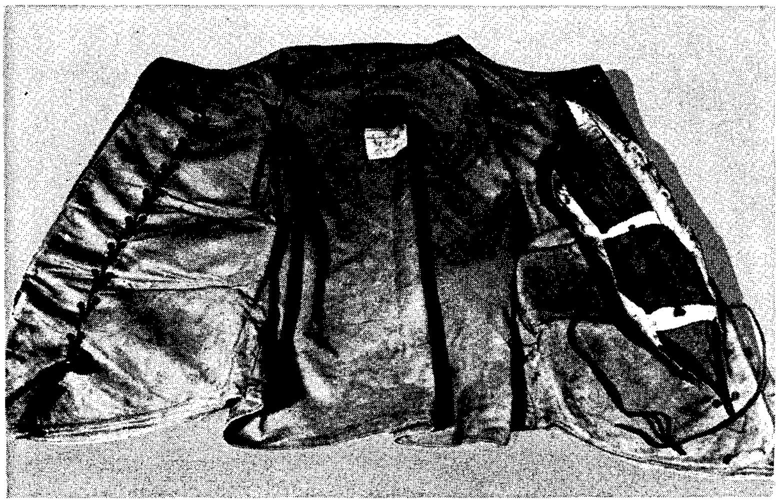

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FIGURE 336.—Japanese body armor, showing internal construction.

23 December 1943 Colonel W. C. Cauthen, Chief Ordnance Officer, USASOS, APO 501, wrote asking that the vest which I designed be submitted to the Chief of Ordnance. This vest was taken to the Ordnance at APO 501 by me 2 January 1944 and kept by Ordnance 501 for me until my return from duty in New Guinea, 15 April 1944.

15 February 1944 Maj. General N. F. Twining, Commanding General of the 15th Air Force, wrote, asking me to bring my vest to the attention of the Head Flight Surgeon of the 5th Air Force. I was in New Guinea at the time but submitted the vest to the office of the Flight Surgeon at APO 501, 15 April 1944.

20 April 1944 a complete set of blue prints of my vest was made at the office of the Surgeon, 5th Air Force.

23 April 1944, at the direction of the Chief Surgeon, USASOS, APO 501, I submitted a final report of the body armor to the Research and Development Board, Hq., GHQ, APO 500 with an endorsement by the Chief Surgeon, Brig. General G. B. Denit. The receipt of this information was acknowledged by Dr. G. R. Harrison, Chairman of this Board. The final model of the vest submitted by me differed from the Japanese in the following particulars:

"a. The vest and its metal plates are designed in a larger size than the Japanese. The plates were hammered out of steel from plaster casts moulded on a soldier 5′7″ in height weighing 150 pounds. These plates should fit all soldiers except those of an extremely small or large stature. (A marking of "medium" in Japanese characters on one of their vests indicates that they are manufacturing them in more than one size.)

b. The space at the base of the neck just above the breast bone and the region of the large blood vessels just beneath the collar bones are covered in the new design.

c. Better metal protection is given the flanks and the lower part of the abdomen.

d. A metal plate is added on the inside of the back of the vest to cover the base of the spine and the kidney areas.

e. The button arrangement of fastening the vest down the front has been eliminated because it takes too long to discard the vest by this method. The front of the vest should be in one piece. The vest should be fastened by one or two clasps along the left side of the chest and flank, and by a clasp on each broad shoulder strap of the vest. These last two

clasps should be arranged sufficiently low on the shoulder so as not to be pressed on by the rifle when carried on the shoulder or by the butt of the rifle when firing. By this arrangement the vest can quickly be discarded in any direction even with overlying cartridge belts, etc.

f. A small curved strip of metal should be incorporated into each shoulder strap to help prevent the wounds incurred by missiles entering the chest through the space above the collar bones, when a man is charging with the upper part of the body bent forward.

g. In soldiers or sailors in stationary positions, where extra weight is not so important, such as crews of antiaircraft guns, additional metal plates could be added to protect the back and shoulders from gun fire."

I. Ridgeway Trimble,
Lt. Colonel, MC,
Chief of Surgical Service,
118th General Hospital, APO 927

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CHAPTER XII

Wound Ballistics and Body Armor in Korea

Carl M. Herget, Ph. D., Capt. George B. Coe, Ord Corps, and Maj. James C. Beyer, MC

Wound ballistic and body armor studies during the Korean War could draw upon the experiences of studies reported in earlier chapters for valuable orientation and guidance. In addition, results of basic wound ballistic investigations (including body armor studies) conducted in the laboratory were available to aid in the interpretation of field findings. Thus, when hostilities opened in Korea in June 1950, developments for field protection which had been planned during World War II reassumed vitality.

Before the opening of hostilities in Korea, the Biophysics Division of the Chemical Corps Medical Laboratories had been carrying out basic research in the fields of wound ballistics and body armor.[1] These studies entailed a comprehensive evaluation of the wounding potential of many types of missiles, especially small arms projectiles and fragments, when striking animal tissue. Samples of armor material, including nylon, doron (fiber glass), steel, aluminum, and combinations of these had also been tested to ascertain the relative protection these materials afforded the animal head, thorax, and abdomen against the different types of missiles. This work was facilitated by background ballistic studies on these materials at Ordnance Department installations, particularly Watertown Arsenal, Mass., and Aberdeen Proving Ground, Md.

BATTLE CASUALTY SURVEY—NOVEMBER 1950

With the advent of hostilities in Korea, the Biophysics Division, Chemical Corps Medical Laboratories, in coordination with Brig. Gen. (later Maj. Gen.) William M. Creasy, Commanding General, Chemical Corps Research and Engineering Command, recommended to Col. (later Brig. Gen.) John R. Wood, MC, Chairman, Medical Research and Development Board, Office of the

[1] (1) Tillett, C. W. III, Herget, C. M., and Odell, F. A.: Preliminary Study on Body Armor Protection From Wounding. CmlC Medical Division Report No. 165, October 1948. (2) Tillett, C. W. III, Banfield, W. G. Jr., and Herget, C. M.: The Effect of a Non-Perforating Missile on the Animal Body Protected by Nylon Armor. CmlC Medical Division Report No. 208, August 1949. (3) Tillett, C. W. III, Banfield, W. G. Jr., and Herget, C. M.: The Effect of a Non-Perforating Projectile on the Animal Body Protected by Steel Armor. CmlC Medical Division Report No. 228, December 1949. (4) Tillett, C. W. III, Banfield, W. G. Jr., and Herget, C. M.: The Mechanism of Thoracic Injury Under Rigid Armor. CmlC Medical Laboratories Research Report No. 93, December 1951. (5) Coe, G. B., Michalski, J. V., Light, F. W., and Herget, C. M.: Effectiveness of Protection From Wounding by Doron and Spot-Bonded Nylon Body Armor. CmlC Medical Laboratories Research Report No. 103, March 1952.

Surgeon General, that a wound ballistics team be organized and dispatched to the Far East Command for the purpose of studying casualties. In response to this recommendation, a team was organized and dispatched to the Far East Command on 14 November 1950 under Department of the Army Orders, AGPA–OS 200.4. Officer members of the team included Lt. Col. Robert H. Holmes and Capt. Robert F. Palmer of the Medical Corps; Capt. William R. Phillips, Ordnance Corps; and 1st Lt. George B. Coe, Chemical Corps. The unit arrived at Haneda Air Terminal, Tokyo, Japan, on 26 November 1950, and reported directly to Maj. Gen. Edgar Erskine Hume, The Surgeon, Far East Command.

No specific plan for the actual functioning of this research unit was previously determined; that is, whether to operate as a completely independent unit with or without T/D (table of distribution) or to arrange an attachment to a theater organization. After a local evaluation, it was recommended to the operations officer, Office of the Surgeon, Far East Command, that the Wound Ballistics Research Team be attached to the 406th Medical General Laboratory, Tokyo. This recommendation had already been approved by Lt. Col. (later Col.) Robert L. Hullinghorst, MC, commanding officer of the laboratory. The attachment was made, and subsequent events proved the decision most wise. This arrangement afforded a headquarters with easy accessibility, office space, a simple means of supply and a ready source of information as to location of medical units and routes of casualty evacuation, and introduction in general to proper channels of command.

Conduct of Survey

After equipment and enlisted personnel were received, approximately 15 December 1950, request was made for entry into the Eighth U.S. Army Area, specifically Pyongyang (fig. 337), for attachment to the 171st Evacuation Hospital. An alternate request was also made for entry into the X Corps Area with attachment to any available MASH (mobile army surgical hospital). Because of the entry of Chinese Communist Forces into the Korean War on about 28 November 1950 and the strategic withdrawal of the United Nations troops to a position below the 38th parallel, the team's entry into Korea was denied. The exigencies of such warfare required that all personnel and equipment permitted entry should contribute directly and immediately to the survival of combat elements.

In the meantime, a study of casualties was begun in Japan at the Tokyo Army Hospital and the 118th Station Hospital at Fukuoka. Eventually, authority was obtained for certain members of the team to enter Korea. These members actually went as blood couriers and were then allowed to remain in Korea, where they were attached to the 3d Station Hospital at Pusan. Even though the flow of casualties at this point in Korea was moderate, several hundred patients with wounds that had received only the minimum in definitive medical care were studied by the team. The team also spent 2 weeks in the

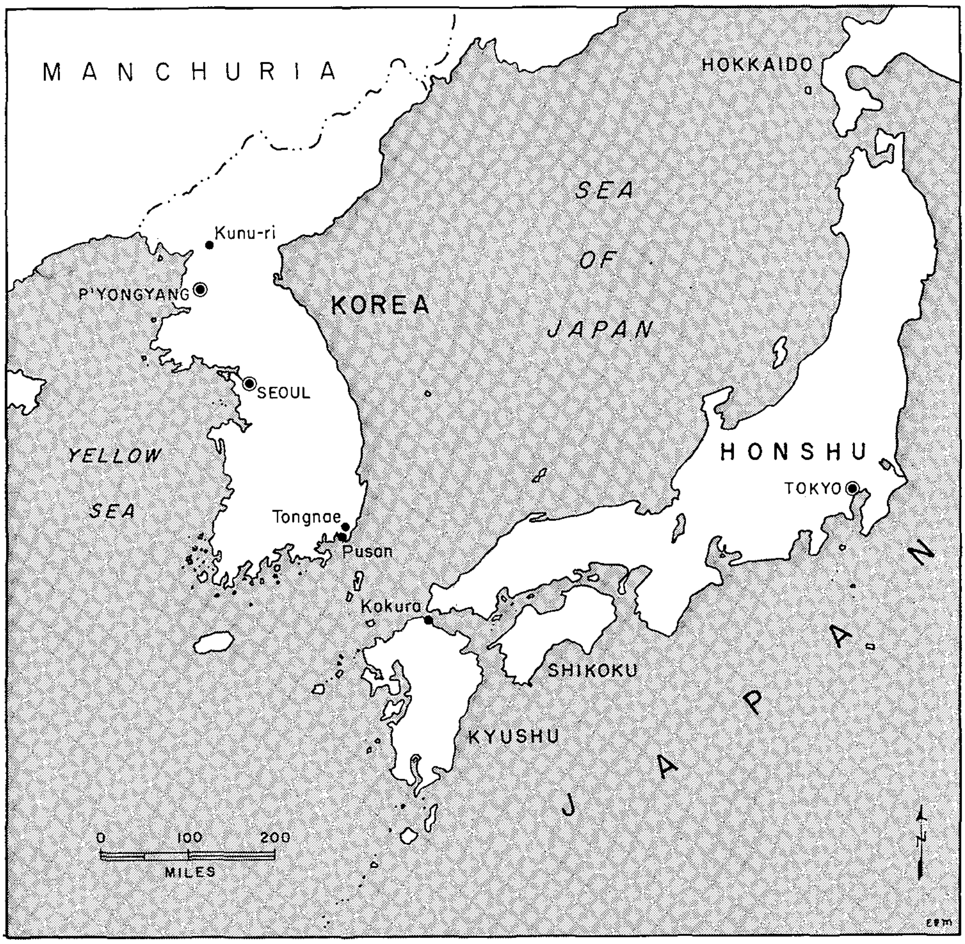

FIGURE 337.—Orientation map, Korea.

prisoner-of-war hospital at Tongnae. Through an interpreter, a thousand wounded North Korean and Chinese Communist soldiers were interviewed as to their mode of wounding, whether it be from aircraft or ground arms and what the wounding missile was. This information furnished some idea of the effect of United Nations weapons on the enemy. A study of U.S. KIA casualties at the Graves Registration Service was also accomplished at this time. However, this survey, made from records only, was of a statistical nature and is not considered a true picture of the type of missiles, wounds, and regional and area frequency of lethal wounds U.S. KIA actually received. Medical records giving type of missile and type of wounds were frequently found to be erroneous. Battlefield surgeons often did not differentiate between a gunshot wound and a shell fragment wound by external examination and often confused penetrating and perforating wounds. Correctness of information on these

points is extremely important for the accuracy of any wound ballistics study. Training in experimental wound ballistics is necessary in order to assure accuracy of the casualty surveys.[2]

Basic Scope of a Battle Casualty Survey

The basic object of all battlefield casualty studies is to analyze the effect of firearms and their missiles upon human or experimental animal tissue. Modern warfare has become so versatile and changes in weapons have been so rapid that for military purposes a study of this nature must be continuous in both the experimental laboratory and every theater of combat operations. These studies must extend in range from simple missile laceration to the complicated effects of atomic weapons explosions and from the first medical care in a battalion aid station to the point of maximum recovery in a general hospital or permanent disposition to a veteran's facility. As each new weapon appears, its wounding properties must be carefully evaluated. This study entails liaison with military intelligence and ordnance; identification of enemy weapons and missiles; knowledge of velocities, size, shape, and mass of missiles; percentage incidence of various missiles; and percentage a given body region is involved, as well as the proper classification of wounds. The study should also evaluate the method, time, and distance of evacuation in relation to primary wound treatment, wound contamination, and all other variables of wound repair. A field wound ballistics study ideally includes a continuous study of the wound from the time of occurrence until the time of maximum repair followed by a study of the functional effects of that repair and the various adaptation phenomena. Therefore, such a study demands the cooperation and coordination of a vertical segment of medical personnel indoctrinated in this continuity of wound evaluation so that sample-type wounds will receive standardized observations and photographic recording at critical intervals, throughout the scheme of medical evacuation and hospitalization.

The following criteria were formulated by this first survey team and are a natural part of any battle casualty survey investigation:

1. Regional frequency of wounds (number of times a region is involved in total number of cases).
2. Regional distribution of wounds (number of wounds in each region in total number of wounds).
3. Weapon and missile identification.
4. Missile frequency; that is, the number of times a given missile type is encountered.
5. Type of wound, distribution, and frequency.
6. Photography of wounds and organs and X-rays of body regions.
7. Special studies; for example, vascular and nerve damage, spinal cord damage, eye and ear damage, fractures, amputations, cold injury, and disease coincident with wounds.
8. SIW (self-inflicted wound) casualties, type of weapon, missile, regional and area frequency, and distribution.

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[2] Trained personnel of a battle casualty survey unit and indoctrination of medical personnel during peacetime maneuvers would facilitate the gathering of accurate data.—J. C. B.

9. Studies on wounded prisoners of war and enemy killed in action to learn the effects of U.S. weapons.
10. The ratio of single to multiple wounding.
11. The effect of wound contamination, tetanus, and gas gangrene.
12. A survey of the casualty flow as sample days in a battalion aid station, mobile army surgical hospital, and evacuation hospital. These studies should represent various tactical circumstances and would aid in future planning procedures.
13. A study of the mode, distance, and time of medical evacuation of casualties and the effects upon the different types of wounds.
14. A study of wound incidence, type and causative agent in the veteran of 60–90 days' combat as compared to the nonveteran of less than 30 days and the veteran of more than 120 days.
15. A study of wound incidence in personnel who have received some form of rotation duty in contrast to a similar group who have not received rotation.
16. A general study of traumas, other than missile-inflicted wounds.

These points are but a partial listing of the studies required in a complete battle casualty study. Some of them have been accomplished, but others are only projected. Fortunately, there are a few medical observers from World War I and many with World War II experience available to thrash out their varied impressions. Of great importance is the fact that many precedents in wound classification, treatment, evacuation, and disposition have been established. Experienced medical personnel are available to lead the way.[3]

Sample of Information Desired

A consideration of war wounds thus begins with an emphasis placed upon the accurate recording of specific medical data. The following items are a more detailed breakdown of some of the previously listed subjects:

The etiologic agent:

1. What kind of missile was it? Size, weight, shape, type metal?
2. Did the missile go through the tissues, or was it retained?
3. What was the weapon—enemy or friendly? Air or ground?
4. What was the approximate range of fire? Explosion distance? Angle of incidence?
5. What was the probable velocity of the missile?
6. Was the missile single or multiple?
7. Was the hit direct fire or ricochet?
8. Are any secondary missiles present, such as equipment, clothing fragments, or other debris?

Accessory military data:

1. What was the individual doing at the time he was struck? Organization? His assignment?
2. Where was he? (in the open, dugout, etc.)
3. What kind of weapon? Terrain? Tactical situation? Weather?
4. Degree of exposure? Fatigue? Time in combat?
5. Previously wounded? When?

[3] Unfortunately, no serious attempt has been made, as yet, to establish these personnel on a permanent basis and provide them with the necessary training and liaison with combat and supporting technical services.—J. C. B.

The wound—general (certain of these factors are applicable to the wounded in action only):

1. What was the physical state of the individual at the time of wounding?
2. What was his anatomic position when wounded?
3. What clothes or equipment covered the wound?
4. What type of contamination prevails?
5. How old is the wound?
6. What prior treatment has been given?
7. What is the general physical condition of the individual now?
8. What type of wound is it? Contusion? Laceration? Penetration? Perforation, etc.?
9. Are there additional wounds?
10. Is the part warm, hot, or cold, pallid or erythematous?
11. Is it painful or tender? Degree?
12. Is the wound dry, oozing, crusted, infected, clean or dirty?
13. How much blood and plasma have been given? When? Any evidence of reaction?
14. Is there a disease or other injury complicating the missile wound?
15. Has there been undue physical exposure since wounding?

The wound—special:

1. What is the exact anatomic location of the wound of entrance? Missile passage? What are the sizes and shapes?
2. Is there a laceration angle of the wound of entrance? Are the edges inverted? Smooth or ragged? Discolored?
3. Is there a contact ring or erythema?
4. Is there a lymphangitis?
5. Is the wound superficial or deep? Slight, moderate, or severe?
6. Is there a fracture? How much have bone fragments acted as secondary missiles?
7. Is there nerve or vascular damage?
8. Is the tissue crepitant? Is it air or body fluid? What kind of odor?
9. Is there a retained missile? What kind? Exact location?
10. How much muscle damage?
11. What is the size of the permanent tissue cavity formed by the missile's passage?
12. Is there an incarcerated hematoma?
13. How great is the tissue loss?
14. What is the exact anatomic location of the wound of exit? Are the edges inverted? Smooth, wedge-shaped? Size?

The conclusions reached by the first wound ballistics team concerning the administrative conduct of such a team are as follows:

A wound ballistics research team should be available in every theater of combat operation. The personnel component should be flexible and determined by the nature of the particular mission. No T/D is recommended. Specific advantages are achieved by having the unit on TDY (temporary duty) to the theater. This permits the complete preservation of objectivity in the study, enthusiasm of a small group of interested and trained personnel to see a project quickly and well done, the knowledge of a deadline for completion, and the opportunity to leave the war zone and review the findings in clear perspective.

A letter of introduction and a careful definition of the mission should precede and accompany the team. Considerable tact is essential in preserving proper channels. Future teams are often judged initially on the basis of impressions left by their predecessors.

A wound ballistics research team on TDY to a combat theater should be attached immediately upon arrival to a local unit with a senior commanding officer. Supply and

housing are thus easily managed. A letter of authority should precede and accompany the team for the issuance of supplies.

Data regarding regional incidence of wounds and missile frequency should be quickly disseminated to the theater surgeon for his use in staff presentation.

Findings of Survey Unit

The findings [4] of the first battlefield wound ballistics team of the Korean War will now be summarized, and tables giving the detailed information will then follow. The body regions and their projected percent of the whole were determined according to the method of Burns and Zuckerman [5] using, however, two additional views of the prone position. Body regions by this method gave the following mean projected areas (fig. 338) and percentages:

	Square feet	*Percent*
Head and neck	0.50	12
Chest	.67	16
Abdomen	.46	11
Upper extremities	.92	22
Lower extremities	1.65	39
Total	4.20	100

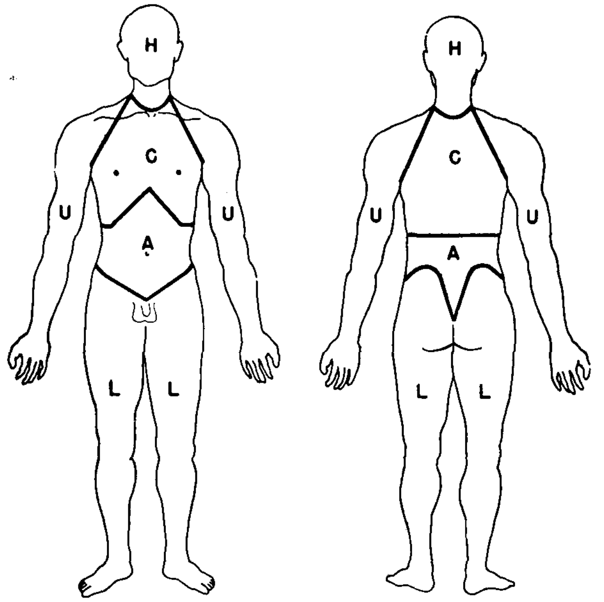

FIGURE 338.—Anatomic location of body regions.

[4] Wound Ballistics Survey, Korea, 15 November 1950–5 May 1951, issued by the Medical Research and Development Board, Surgeon General's Office, Department of the Army.

[5] Burns, B. D., and Zuckerman, S.: The Wounding Power of Small Bomb and Shell Fragments. R. C. No. 350 of the Research and Experiments Department of the Ministry of Home Security.

Wound ballistic data on 4,600 WIA casualties[6] indicated the following:

1. Most wounds in WIA casualties in Korea for the period from 15 November 1950 to 5 May 1951 were caused by fragments (approximately 92 percent) rather than by small arms (approximately 7.5 percent).

2. The shell fragments were primarily mortar and grenade, since the enemy had used little heavy artillery.

3. Most wounds were of a penetrating (72.7 percent) rather than a perforating (20.3 percent) type.

4. The 4,600 WIA casualties received 7,773 wounds. Therefore, the wound incidence was 1.69 wounds per casualty.

The regional distribution of wounds in personnel wounded in action by body region is shown in table 252.

Analysis of the missile type and regional distribution of wounds in these 4,600 casualties is presented in table 253.

The wounding agents and the number of wounds in each area of a body region are presented in tables 254 through 259.

The type and frequency of the 7,773 wounds analyzed in the 4,600 cases is shown in table 260 with each area of a body region tabulated in tables 261 through 266.

TABLE 252.—*Regional distribution of 7,773 wounds in 4,600 WIA casualties*

Region	Number of wounds	Percent of total wounds
Head and neck	1, 275	16. 4
Thorax	613	7. 9
Abdomen	481	6. 2
Extremities:		
Upper	1, 948	25. 0
Lower	3, 394	43. 7
Genitalia	62	. 8
Total	7, 773	100. 0

[6] The medical records of a total of 4,600 cases with 7,773 wounds were reviewed at the Tokyo Army Hospital from 1 Dec. 1950 to 15 Feb. 1951. The data for this section were obtained from those records.

TABLE 253.—*Regional distribution of 7,773 wounds in 4,600 WIA casualties, by wounding agent*

Wounding agent	Head	Thorax	Abdomen	Extremities		Genitalia	Total wounds	
				Upper	Lower		Number	Percent
Fragment	1, 091	539	414	1, 616	2, 825	51	6, 536	84. 09
Mortar	68	27	14	114	151	7	381	4. 90
Grenade	29	6	9	40	60	1	145	1. 87
Landmine	18	1	2	9	23		53	. 68
Bomb			1	1	2		4	. 05
Machinegun	7	5	13	17	56		98	1. 26
Rifle	40	31	25	128	242	3	469	6. 03
Pistol	1	1		3	8		13	. 17
Burn	5	2	1	11	9		28	. 36
Phosphorus	2			9	14		25	. 32
Secondary	14	1	2		4		21	. 27
Total	1, 275	613	481	1, 948	3, 394	62	7, 773	100. 0

TABLE 254.—*Area distribution of 1,275 head wounds in 4,600 WIA casualties, by wounding agent*

Wounding agent	Region of skull				Brain	Scalp	Face	Maxilla	Mandible	Nose	Ear	Eyelid	Eyeball	Neck	Cervical vertebra	Total wounds
	Frontal	Temporal	Occipital	Parietal												
Fragment	56	46	25	66	46	52	163	54	83	21	35	39	254	138	13	1, 091
Mortar	4		2	2	1	2	13	2	8	1	3	3	20	7		68
Grenade	1					1	6	1	1		1	3	12	3		29
Landmine							5					2	7	4		18
Machinegun						1				1			1	4		7
Rifle	2	2	3	6	4		1	3	9				5	5		40
Pistol													1			1
Burn							4						1			5
Phosphorus	1						1									2
Secondary						1	2	1					10			14
Total	64	48	30	74	51	57	195	61	101	23	39	47	311	161	13	1, 275

TABLE 255.—*Distribution of 613 wounds of the thorax in 4,600 WIA casualties (160 cases of hemothorax), by wounding agent*

Wounding agent	Number of wounds	Wounding agent	Number of wounds
Fragment	539	Rifle	31
Mortar	27	Pistol	1
Grenade	6	Burn	2
Landmine	1	Secondary	1
Machinegun	5		
		Total	613

TABLE 256.—*Area distribution of 481 wounds of the abdomen in 4,600 WIA casualties, by wounding agent*

Wounding agent	Abdomen [1]	Stomach	Liver	Spleen	Small intestine	Colon	Rectum	Anus	Kidney	Bladder	Total wounds
Fragment	261	17	22	15	35	38	10	1	6	9	414
Mortar	4	7	1		1	1					14
Grenade	3	1	1		2	2					9
Landmine	2										2
Bomb	1										1
Machinegun	7		2		1	2			1		13
Rifle	12		3	2	4	3			1		25
Burn	1										1
Secondary		1	1								2
Total	291	26	30	17	43	46	10	1	8	9	481

[1] Specific region not specified.

TABLE 257.—*Area distribution of 1,948 wounds of the upper extremities in 4,600 WIA casualties, by wounding agent*

Wounding agent	Shoulder	Axilla	Arm	Elbow	Forearm	Hand	Fingers	Total wounds
Fragment	335	13	529	78	238	303	120	1,616
Mortar	36		36	5	7	28	2	114
Grenade	4	1	10		7	10	8	40
Landmine	1		4			4		9
Bomb						1		1
Machinegun	6		7	1	1	2		17
Rifle	39		28	4	25	27	5	128
Pistol	1			1		1		3
Burn			4			7		11
Phosphorus	2		2		1	4		9
Total	424	14	620	89	279	387	135	1,948

TABLE 258.—*Area distribution of 3,394 wounds of the lower extremities in 4,600 WIA casualties, by wounding agent*

Wounding agent	Buttocks	Hip	Thigh	Knee	Leg	Foot	Toes	Total wounds
Fragment	240	131	797	199	941	478	39	2, 825
Mortar	12	2	41	10	60	26	------	151
Grenade	6	1	10	3	25	12	3	60
Landmine	2	1	6	2	11	1	------	23
Bomb	------	------	------	------	------	2	------	2
Machinegun	3	4	23	1	13	12	------	56
Rifle	14	7	87	20	71	41	2	242
Pistol	1	2	1	------	1	3	------	8
Burn	3	------	1	------	4	1	------	9
Phosphorus	2	------	4	1	6	1	------	14
Secondary	------	------	------	1	3	------	------	4
Total	283	148	970	237	1, 135	577	44	3, 394

TABLE 259.—*Area distribution of 62 wounds of the genitalia in 4,600 WIA casualties, by wounding agent*

Wounding agent	Scrotum	Penis	Testicles	Total wounds
Fragment	31	17	3	51
Mortar	4	3	--------	7
Grenade	1	--------	--------	1
Rifle	1	1	1	3
Total	37	21	4	62

TABLE 260.—*Distribution of 7,773 wounds in 4,600 WIA casualties, by type of wound*

Type of wound	Number of wounds	Percent of total wounds
Penetration	5, 653	72. 7
Perforation	1, 578	20. 3
Laceration	338	4. 4
Amputation	96	1. 2
Avulsion	59	. 8
Contusion	49	. 6
Total	7, 773	100. 0

TABLE 261.—*Area distribution of 1,275 head wounds in 4,600 WIA casualties, by type of wound*

Area	Penetration	Perforation	Superficial	Laceration	Contusion	Avulsion	Concussion	Total wounds
Scalp	31	2	4	18	2	2	------	59
Region of skull:								
Frontal	54	1	2	5	------	------	13	75
Temporal	47	1	1	4	------	------	2	55
Parietal	71	1	------	4	------	------	2	78
Occipital	23	------	------	2	------	------	1	26
Brain	38	2	------	8	7	------	9	64
Face	162	7	6	14	------	------	1	190
Maxilla	47	3	------	6	1	------	------	57
Mandible	75	15	------	4	------	1	------	95
Nose	17	5	1	------	------	------	------	23
Eyelid	28	3	------	14	1	1	------	47
Eyeball	254	18	5	8	3	6	------	294
Ear	30	3	1	5	1	2	1	43
Neck	132	16	4	6	------	------	------	158
Cervical vertebra	8	3	------	------	------	------	------	11
Total	1,017	80	24	98	15	12	29	1,275

TABLE 262.—*Distribution of 613 wounds of the thorax in 4,600 WIA casualties, by type of wound*

Type of wound	Rib cage	Thoracic vertebra	Back [1]	Total wounds
Penetration	414	19	80	513
Perforation	51	3	10	64
Superficial	11	--------	4	15
Laceration	10	1	3	14
Contusion	2	1	2	5
Avulsion	1	--------	1	2
Total	489	24	100	613

[1] Specific site not specified.

TABLE 263.—*Area distribution of 481 wounds of the abdomen in 4,600 WIA casualties, by type of wound*

Type of wound	Abdominal wall	Inguinal region	Lumbar region	Sacral region	Stomach	Spleen	Liver	Kidney	Bladder	Small intestine	Colon	Rectum	Anus	Posterior	Total wounds
Penetration	140	4	28	1	3	7	11	3	6	12	15	4	1	74	309
Perforation	38	1	3	1	5	3	14	4	3	24	27	5		10	138
Superficial	4			1						1	2	1		3	12
Laceration	4					1	2	1		1	1			3	13
Contusion	1							1		1				3	6
Avulsion	1		1											1	3
Total	188	5	32	3	8	11	27	9	9	39	45	10	1	94	481

TABLE 264.—*Area distribution of 1,948 wounds of the upper extremities in 4,600 WIA casualties, by type of wound*

Type of wound	Axilla	Shoulder	Arm	Elbow	Forearm	Hand	Fingers	Total wounds
Penetration	13	310	455	67	207	262	90	1, 404
Perforation		92	121	26	68	77	32	416
Superficial		8	15	2	2	7		34
Laceration		8	6		4	11	3	32
Contusion		1	3	1		3		8
Avulsion		1	1		2	5	4	13
Amputation			6	2	1	6	26	41
Total	13	420	607	98	284	371	155	1, 948

TABLE 265.—*Area distribution of 3,394 wounds of the lower extremities in 4,600 WIA casualties, by type of wound*

Type of wound	Buttocks	Hip	Thigh	Knee	Leg	Foot	Toes	Total wounds
Penetration	231	117	644	170	779	377	26	2, 344
Perforation	42	20	275	54	283	171	15	860
Superficial	5	1	11	3	17	5		42
Laceration	4	4	16	5	14	10	1	54
Contusion		3			6	4		13
Avulsion	7		5	6	3	5	1	27
Amputation			10	2	25	11	6	54
Total	289	145	961	240	1, 127	583	49	3, 394

TABLE 266.—*Area distribution of 62 wounds of the genitalia in 4,600 WIA casualties, by type of wound*

Type of wound	Scrotum	Penis	Testicle	Total wounds
Penetration	32	15	2	49
Perforation	3	3	1	7
Laceration	3	2		5
Avulsion	1			1
Total	39	20	3	62

Single Versus Multiple Wounding

Another analysis was made for the single and multiple wounding for the WIA cases studied. The following possibilities were considered: (1) A single wound in one area, (2) a single wound in one area and a single wound in another, (3) a single wound in one area with multiple wounds in another, (4) multiple wounds in one area, (5) multiple wounds in the area under study (called the local area) and a single wound in another area, and (6) multiple wounds in the local area and multiple wounds elsewhere. Table 267 summarizes the incidence of single versus multiple woundings in 4,600 casualties with 7,467 wounds known to be either single (2,621) or multiple (4,846). Of the total 7,773 wounds, the type of wounding (single or multiple) was unknown for 306 wounds.

TABLE 267.—*Distribution of 7,467 wounds in 4,600 WIA casualties, by type of wounding*

Type of wounding	Number of wounds	Percent of wounds
Single local, single elsewhere	3, 312	44. 3
Single local	2, 621	35. 1
Multiple local, multiple elsewhere	1, 001	13. 4
Single local, multiple elsewhere	257	3. 5
Multiple local	173	2. 3
Multiple local, single elsewhere	103	1. 4
Total	7, 467	100. 0

Although each casualty averaged a 1.69 wound incidence, 35 percent showed only a single wound in one area and 44 percent showed a single wound in one area with only a single wound in another area. These findings are significant in that such a large percentage of wounded in action (79 percent) shows only one or two wounds. Since approximately 89 percent of the total wounds were caused by shell fragments, usually mortar or grenade, the chance factor of being struck is emphasized even though the missile density is quite great. It would appear that a bursting mortar shell or grenade if near enough to produce one wound would have an excellent chance to produce many wounds with its fragmentation-spray pattern. A few instances of this were seen, but as shown in the tables most of the fragments actually miss. How many strike another individual is not known. Tables 268 through 273 list the single versus multiple wounding according to the various body regions.

TABLE 268.—*Area distribution of 1,189 wounds of the head in 4,660 WIA casualties, by type of wounding*

Type of wounding	Region of skull				Brain	Scalp	Ear	Face	Maxilla	Mandible	Eye	Nose	Neck	Cervical vertebra	Total wounds
	Frontal	Temporal	Occipital	Parietal											
Single local	19	13	10	39	10	23	10	21	12	37	64	2	41	4	305
Single local, single elsewhere	23	25	12	24	36	24	23	69	32	46	140	15	53	6	528
Single local, multiple elsewhere	4	3	1	3	2	------	1	8	2	1	40	3	15	------	83
Multiple local	2	1	2	2	2	1	------	7	------	2	24	------	1	2	46
Multiple local, single elsewhere	1	1	------	------	------	------	------	13	------	2	1	------	6	------	24
Multiple local, multiple elsewhere	8	4	1	5	------	3	4	74	9	7	68	2	18	------	203
Total	57	47	26	73	50	51	38	192	55	95	337	22	134	12	1, 189

TABLE 269.—*Area distribution of 594 wounds of the thorax in 4,600 WIA casualties, by type of wounding*

Type of wounding	Pulmonary	Rib cage	Heart	Thoracic vertebra	Back	Total wounds
Single local	1	179	------	9	26	215
Single local, single elsewhere	2	221	------	12	47	282
Single local, multiple elsewhere	------	12	1	------	3	16
Multiple local	------	10	------	------	2	12
Multiple local, single elsewhere	------	6	------	1	4	11
Multiple local, multiple elsewhere	------	42	------	1	15	58
Total	3	470	1	23	97	594

TABLE 270.—*Area distribution of 466 wounds of the abdomen in 4,600 WIA casualties, by type of wounding*

Type of wounding	Abdominal wall	Posterior	Stomach	Liver	Spleen	Small intestine	Colon	Rectum	Anus	Kidney	Bladder	Lumbar vertebra	Sacral vertebra	Total wounds
Single local	59	27	2	5	1	4	7	3	1	------	1	14	1	125
Single local, single elsewhere	102	46	5	14	8	29	28	8	------	7	8	13	------	268
Single local, multiple elsewhere	8	3	------	2	------	------	3	------	------	------	------	1	------	17
Multiple local	5	3	------	2	------	1	2	------	------	------	------	2	------	15
Multiple local, single elsewhere	3	3	------	------	------	------	------	------	------	------	------	------	------	6
Multiple local, multiple elsewhere	11	15	1	2	------	3	1	------	------	------	------	2	------	35
Total	188	97	8	25	9	37	41	11	1	7	9	32	1	466

TABLE 271.—*Area distribution of 1,908 wounds of the upper extremities in 4,600 WIA casualties, by type of wounding*

Type of wounding	Axilla	Shoulder	Arm	Elbow	Forearm	Hand	Fingers	Total wounds
Single local	2	149	156	32	116	114	31	600
Single local, single elsewhere	6	206	308	46	113	156	65	900
Single local, multiple elsewhere	3	14	21	3	8	14	6	69
Multiple local	------	4	5	1	4	13	5	32
Multiple local, single elsewhere	------	6	9	1	------	6	1	23
Multiple local, multiple elsewhere	1	41	115	8	31	66	22	284
Total	12	420	614	91	272	369	130	1, 908

TABLE 272.—*Area distribution of 3,252 wounds of the lower extremities in 4,600 WIA casualties, by type of wounding*

Type of wounding	Buttocks	Hip	Thigh	Knee	Leg	Foot	Toe	Total wounds
Single local	80	49	412	118	406	285	23	1, 373
Single local, single elsewhere	133	77	403	86	404	173	10	1, 286
Single local, multiple elsewhere	7	6	12	1	28	14	2	70
Multiple local	7	2	14	10	15	19	------	67
Multiple local, single elsewhere	3	------	2	4	23	7	------	39
Multiple local, multiple elsewhere	47	13	85	24	189	50	9	417
Total	277	147	928	243	1, 065	548	44	3, 252

TABLE 273.—*Area distribution of 58 wounds of the genitalia in 4,600 WIA casualties, by type of wounding*

Type of wounding	Penis	Scrotum	Testicles	Total wounds
Single local	1	2	--------	3
Single local, single elsewhere	15	30	3	48
Single local, multiple elsewhere	1	1	--------	2
Multiple local	--------	1	--------	1
Multiple local, multiple elsewhere	2	2	--------	4
Total	19	36	3	58

Incidence of Fractures

Among the 4,600 casualties, there was a total of 1,762 fractures (table 274). The incidence of fractures of the known body areas was 44.4 percent for the lower extremities, 34.8 percent for the upper extremities, 13.5 percent for the head, 4.5 percent for the thorax, and 0.9 percent for the vertebral column. Approximately one out of four casualties had a fracture and almost one out of two was evacuated to the Zone of Interior.

TABLE 274.—*Distribution of 1,762 fractures in 4,600 WIA casualties, by site of fracture*

Site of fracture	Number of fractures	Percent for body area
Lower extremities:		
Foot	261	33. 4
Leg	246	31. 4
Femur	164	21. 0
Knee	57	7. 3
Toe	30	3. 8
Hip	24	3. 1
Total	782	100. 0
Upper extremities:		
Arm	154	25. 2
Hand	150	24. 6
Forearm	108	17. 7
Shoulder	90	14. 7
Fingers	63	10. 3
Elbow	46	7. 5
Total	611	100. 0
Head and neck:		
Mandible	66	27. 7
Parietal lobe	56	23. 5
Frontal lobe	37	15. 6
Temporal lobe	21	8. 8
Maxilla	13	5. 5
Nose	7	2. 9
Face	6	2. 5
Ear	3	1. 3
Eye (orbit)	2	. 8
Vertebra (cervical)	23	9. 7
Unknown	4	1. 7
Total	238	100. 0

TABLE 274.—*Distribution of 1,762 fractures in 4,600 WIA casualties, by site of fracture*—Continued

Site of fracture	Number of fractures	Percent for body area
Thorax:		
Ribs	68	85. 0
Vertebra	12	15. 0
Total	80	100. 0
Abdomen:		
Lumbar vertebra	15	94. 0
Sacral vertebra	1	6. 0
Total	16	100. 0
Site unknown	35	

Excluding 51 fractures (16 vertebral and 35 site unknown), it was found that slightly more than 90 percent of the fractures were compound comminuted.

Of the 4,600 WIA casualties, 34 (0.7 percent) died of wounds. Of the remaining 4,566 casualties, 2,893 (62.9 percent) were evacuated to the Zone of Interior and 1,673 (36.4 percent) were returned to duty (table 275).

TABLE 275.—*Disposition of 4,566 WIA casualties, by region wounded*

Region wounded	Returned to duty	Evacuated to the Zone of Interior	Total casualties
	Number	*Number*	*Number*
Extremities:			
Lower	938	1, 209	2, 147
Upper	284	767	1, 051
Head	230	502	732
Thorax	132	226	358
Abdomen	83	167	250
Genitalia	6	22	28
Total	1, 673	2, 893	4, 566

Peripheral Nerve Injuries

A study of peripheral nerve wounds was also made, at the Tokyo Army Hospital, on 200 cases sustaining this type of injury, and the data were analyzed for causative agent (table 276). In order to obtain these 200 peripheral nerve cases, it was necessary to examine the records of 1,872 cases.

TABLE 276.—*Distribution of 200 cases with peripheral nerve wounds, by causative agent and anatomic location of nerves*

Anatomic location of nerve	Missile unknown	Gunshot	Mortar	Shell fragment, caliber unknown	Hand grenade	Artillery shell	Land-mine	Machine-gun	Total cases
Head:									
Facial	7	------	------	------	------	------	------	------	7
Mandibular	2	1	------	------	------	------	------	------	3
Maxillary	1	2	1	------	------	------	------	------	4
Total	10	3	1	------	------	------	------	------	14
Upper extremities:									
Axillary	------	2	------	------	------	------	------	------	2
Radial	24	7	7	2	------	1	------	------	41
Ulnar	23	9	4	1	------	1	1	------	39
Median	13	1	2	1	1	1	------	------	19
Brachial	4	2	------	2	------	------	------	------	8
Total	64	21	13	6	1	3	1	------	109
Lower extremities:									
Tibial	19	1	2	1	------	------	------	------	23
Femoral	7	1	------	1	------	------	------	1	10
Peroneal	14	3	2	------	------	------	------	------	19
Popliteal	4	------	------	------	------	------	------	------	4
Plantar	------	------	------	1	1	------	------	------	2
Cutaneous	4	2	1	------	------	------	------	------	7
Sciatic	8	------	------	------	------	------	------	1	9
Pudendal	2	1	------	------	------	------	------	------	3
Total	58	8	5	3	1	------	------	2	77
Grand total	132	32	19	9	2	3	1	2	200

Vascular Wounds

Concurrently, a survey was made on vascular wounds, records of which were available on 100 cases (tables 277, 278, and 279). In order to obtain this sample, it was necessary to examine the records of 2,609 battle casualties.

TABLE 277.—*Distribution of 100 cases of vascular damage, by type of wound*

Type of wound	Artery	Artery and vein	Vein	Total wounds
Penetrating	42	12	1	55
Perforating	39	3	1	43
Lacerating	1			1
Contused	1			1
Total	83	15	2	100

TABLE 278.—*Distribution of 100 cases of vascular damage and associated bone and nerve injury*

Vascular and associated injury	Artery	Artery and vein	Vein	Total wounds
Fracture	5	3		8
Nerve damage	19			19
Fracture and nerve damage	39			39
Fracture, nerve and vascular to be determined [1]	7			7
Aneurysm	3	11		14
Vascular damage alone	10	1	2	13
Total	83	15	2	100

[1] In these cases, there was clinical evidence of vascular and/or nerve damage but its exact location had not been defined.

TABLE 279.—*Distribution of 100 cases of vascular injury, by type of missile causing damage*

Type of missile	Artery	Artery and vein	Vein	Total wounds
Missile, unknown	58	13	2	73
Shell fragment, unknown	3			3
Small arms	11	2		13
Machinegun	3			3
Mortar	8			8
Total	83	15	2	100

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The regional and area frequency of the vascular damage in the 100 cases was as follows:

	Number of cases
Head and neck:	
Artery not specified	4
Temporal artery	1
Mandibular artery	2
Carotid artery	1
Carotid artery and vein	3
Thorax, artery not specified	1
Lumbar vertebra, artery not specified	1
Upper extremity:	
Shoulder, artery not specified	1
Axillary artery	2
Brachial artery	10
Brachial artery and vein	2
Radial artery	9
Radial artery and vein	2
Ulnar artery	2
Lower extremity:	
Pudendal artery	2
Femoral artery	14
Femoral artery and vein	3
Femoral vein	2
Popliteal artery	3
Popliteal artery and vein	2
Tibial anterior artery	5
Tibial anterior artery and vein	1
Tibial posterior artery	3
Tibial posterior artery and vein	2
Artery not specified	20
Sural artery	1
Peroneal artery	1
Total	100

Self-Inflicted Wounds

A study of self-inflicted wounds, both accidental and deliberate, revealed that, in the 2,605 wounded cases studied, 116 (4.4 percent) were self-inflicted (table 280).

TABLE 280.—*Distribution of 116 self-inflicted wounds in 2,605 casualties, by region*

Region	Number of wounds	Percent of total wounds
Left lower extremities	53	45.7
Right lower extremities	36	31.0
Left upper extremities	18	15.5
Right upper extremities	5	4.3
Miscellaneous	4	3.5
Total	116	100.0

Survey of Turkish Brigade

The opportunity presented itself to make a casualty survey on wounded personnel all from one unit who were injured during a known period of combat. Members of the Turkish Brigade were interviewed at the Tokyo Army Hospital. This Brigade had been in action for 3 nights and 3 days (from the night of 27 November 1950 to the day of 30 November 1950) in the vicinity of Kunuri, Korea. A total of 407 injured were evacuated to Japan of which 387 were considered to have been hit by enemy missiles (the remainder were disease cases or nonbattle casualties). Of the 387 wounded in action, 286 were individually interrogated. This represented 74 percent of all the WIA casualties evacuated to Japan. The number of WIA casualties who remained in Korea was not known, but the number was believed to be small, and it was thought all were promptly returned to duty.

Interrogations, aided by Turkish officers who were available as interpreters, lasted from 5 to 15 minutes per casualty. What error, if any, was introduced by this procedure is unknown. Answers were usually prompt and direct. Most of the Turkish soldiers appeared very certain of the type of the weapons producing the missiles with which they were hit, sometimes stating the enemy was so close that the weapons were visible, or otherwise being able to give good reasons for distinguishing between mortar and grenade hits. The interrogation was accompanied by examination of the casualty.

The 286 WIA casualties incurred a total of 950 wounds (fig. 339), as listed in table 281.

TABLE 281.—*Distribution of 950 wounds in 286 Turkish WIA casualties, by number of hits on anterior and posterior surface of body region*

Body region	Hits on— Anterior surface		Hits on— Posterior surface		Total hits		Percent of total body area
	Number	Percent	Number	Percent	Number	Percent	
Head	61	6. 4	15	1. 6	76	8. 0	12. 0
Chest	21	2. 2	117	12. 4	138	14. 6	16. 0
Abdomen	31	3. 3	16	1. 6	47	4. 9	11. 0
Extremities:							
Upper	69	7. 3	119	12. 5	188	19. 8	22. 0
Lower	253	26. 6	248	26. 1	501	52. 7	39. 0
Total	435	45. 8	515	54. 2	950	100. 0	100. 0

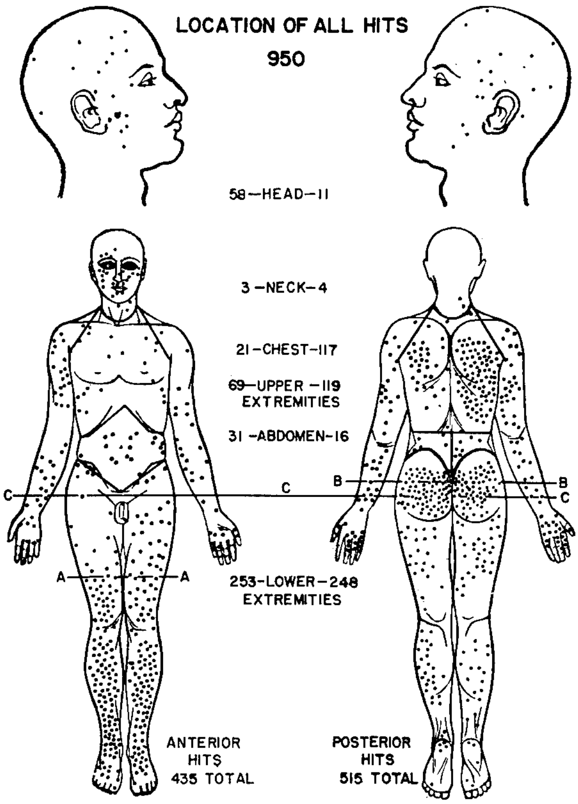

Figure 339.—Location of wounds in 286 Turkish soldiers wounded in action.

The missiles responsible for these wounds are listed in table 282.

An attempt was made to determine the mean estimated length of trajectories for the causative agents from the site of origin to the man hit. No attempt was made to discard any data (such as mortar shell fragment hits alleged to have occurred at a 200–400 meter range). The reported mean ranges were given to establish orders of magnitude, as follows:

Type of missile:	*Mean estimated length of trajectories (in meters)*
Rifle	112.5 ± 101.0
Machinegun	70.7 ± 83.1
Mortar fragments	9.7 ± 18.8
Hand grenade fragments	5.1 ± 4.6

TABLE 282.—*Distribution of 950 hits on 286 Turkish WIA casualties, by type of missile*

Type of missile	Number of hits	Percent of hits
Small arms:		
Rifle	149	15. 7
Pistol	10	1. 1
Machinegun	59	6. 2
Submachinegun	18	1. 9
Unknown	21	2. 2
Total	257	27. 1
Fragment:		
Mortar	559	58. 9
Hand grenade	111	11. 7
Secondary missile	2	. 2
Unknown fragment	20	2. 2
Total	692	73. 0
Antitank gun [1]	1	. 1
Grand total	950	100. 0

[1] Not considered a small arms hit nor a fragment hit.

When the estimated ranges were broken down for missiles causing perforating and penetrating wounds, the results were generally in line with the expectation that missiles producing perforating wounds would come from shorter ranges (that is, have higher velocities):

	Mean estimated ranges (meters)	
Type of missile:	*Missiles causing perforating wounds*	*Missiles causing penetrating wounds*
Rifle	109. 0	118. 0
Machinegun	55. 3	102. 7
Mortar fragment	39. 6	8. 8
Hand grenade fragment	1. 2	6. 0

It will be noted, in the tabulation just listed, that the mortar fragments are reversed from the normal expectation. Had the alleged occurrence of perforating mortar fragment wounds at ranges of over 100 meters been discarded as an error in judgment of range, the mean values would have become 4.3 meters for the perforating missiles and 8.1 meters for the penetrating ones. This relationship is in the proper order.

Degree of damage from various wounding agents was assessed on a 1 to 4 scale (table 283).

TABLE 283.—*Distribution of 233 determinations of the degree of damage caused by each type of missile*

Type of missile	Degree of damage [1]				Total determinations
	1	2	3	4	
Small arms:					
Rifle	67	10		2	79
Pistol	2				2
Machinegun	22		5		27
Submachinegun	7	1	2		10
Unknown	15	1	1		17
Total	113	12	8	2	135
Fragments from—					
Mortar	53	10	1	5	69
Hand grenade	19	3	1	2	25
Unknown missile	2	1			3
Antitank gun				1	1
Total	74	14	2	8	98
Grand total	187	26	10	10	233

[1] Degree 1.—Size of wound of entrance in any one dimension not more than three times the size of missile, provided the missile was not greater than 1 cm. in any dimension.

Degree 2.—Size of defect of the wound of entrance greater than 3 cm. in any one dimension (regardless of missile size) but less than 5 cm. in its greatest dimension.

Degree 3.—Same as degree 2 for defects from 5 to 10 cm. in their greatest dimension.

Degree 4.—Same as degree 3 for defects measuring over 10 cm. in any one dimension.

It was also possible to analyze the incidence of casualties occurring during the day and during the night. A total of 216 casualties were available but, because 30 sustained hits from more than one type of missile, it was necessary to list these more than once. Therefore, the data total 250 casualties and are prescribed in table 284.

Finally, it was possible to estimate the number of enemy casualties resulting from the efforts of 108 Turkish soldiers (table 285). Not shown in the table are the numbers of enemy casualties which the Turks claim to have produced after they (the Turks) had been wounded.

Autopsy Study of DOW Casualties

The reports of autopsy findings on 125 WIA casualties who were hospitalized and died later were made available for study by the 406th Medical General Laboratory. An analysis of the missile type involved in these cases and the immediate cause of death are shown in tables 286 and 287. The head, the thorax, and the abdomen were the principal regions involved, with

TABLE 284.—*Distribution of 250 casualties (152 sustaining hits during the day and 98 during the night), by type of missile*

Type of missile	Day casualties		Night casualties	
	Number	Percent	Number	Percent
Small arms:				
Rifle	67	26. 8	19	7. 6
Pistol	1	. 4	1	. 4
Machinegun	19	7. 6	12	4. 7
Submachinegun	6	2. 4	5	2. 0
Unknown	9	3. 6	8	3. 2
Total	102	40. 8	45	17. 9
Fragments:				
Mortar	31	12. 4	38	15. 2
Hand grenade	15	6. 0	13	5. 3
Unknown	4	1. 6	1	. 4
Antitank gun			1	. 4
Total	50	20. 0	53	21. 3
Grand total	152	60. 8	98	39. 2

TABLE 285.—*Distribution of estimated number of enemy casualties caused by the indicated number of Turkish soldiers, by weapon used*

Weapon	Enemy killed or wounded	Turkish soldiers involved
	Number	*Number*
M1 rifle	268	65
Carbine	5	2
Pistol	4	2
Machinegun	838	16
Submachinegun	45	6
Browning automatic rifle	6	1
Hand grenade	100	17
Bazooka	6	3
Bayonet	22	9
Knife	1	1
Strangled	3	1
Burned	3	1
Total	1, 301	

14.4 percent of the cases showing involvement of the extremities alone. Small arms fire accounted for 56.6 percent of the casualties, and this approximates the incidence seen in KIA casualties. Cases with head wounds showed an average survival time of 12.6 days; thoracic wounds, 4.5 days; abdominal wounds, 14 days; extremity wounds, 7.6 days; and wounds of the spine, 19 days.

TABLE 286.—*Frequency of causative agent producing wounds in 125 DOW casualties, by body region*

Body region	Unknown missile	Gunshot	Shell fragment	Mortar	Grenade	Mine	Bayonet	Crushing	Chemical burns	Total casualties (number)
Head	11	14	7	3	1	----	----	------	------	36
Spine	1	4	1	1	----	----	1	------	------	8
Thorax	1	1	1	1	----	----	----	------	------	4
Abdomen	6	7	1	2	2	----	----	1	------	19
Thorax and abdomen	------	10	1	1	----	----	----	------	------	12
Extremities	2	6	3	1	1	3	1	------	1	18
Abdomen and extremities	1	5	2	------	1	----	----	------	------	9
Thorax and spine	------	3	----	------	----	----	----	------	------	3
Abdomen, thorax, and spine	------	1	2	------	----	----	----	------	------	3
Head and extremities	------	1	2	------	----	----	----	------	------	3
Abdomen and spine	------	2	----	------	----	----	----	------	------	2
Miscellaneous	2	4	1	1	----	----	----	------	------	8
Total	24	58	21	10	5	3	2	1	1	125

Source: Autopsy reports from 406th Medical General Laboratory, Tokyo, Japan.

Study of KIA Casualties

A survey of the records of 1,500 personnel killed in action was conducted at the Quartermaster Graves Registration unit, Pusan, Korea, during January 1951. Of the KIA casualties sustained by the United Nations forces during this period, 63 percent were due to enemy small arms fire, 26.9 percent to shell fragments, 2.8 percent to mortar, 2 percent to mines, 0.7 percent to grenades, 0.5 percent to artillery, and 4.1 percent to miscellaneous agents. This was in marked contrast to the results obtained from an analysis of the WIA cases which showed that fragments of all types were responsible for about 92 percent of the wounds. Table 288 shows the regional frequency of fatal wounds in the 1,500 KIA casualties.

TABLE 287.—*Anatomic cause of death and body region wounded in 125 DOW casualties*

Anatomic cause of death	Head	Vertebra	Thorax	Abdomen	Thorax, abdomen	Extremity	Abdomen, extremity	Thorax, vertebra	Thorax, abdomen, vertebra	Head, extremity	Abdomen, vertebra	Miscellaneous	Total
Brain damage	14												14
Cerebellar hemorrhage			1									1	2
Brain abscess	5												5
Meningitis	5												5
Japanese B encephalitis	7					1							8
Japanese B encephalitis and peritonitis							1						1
Poliomyelitis						1							1
Pneumonia		4					1		1	1		1	8
Other pulmonary	4	2	3					3					12
Myocarditis		1											1
Mediastinal hemorrhage					1								1
Peritonitis				7	4		1		2		1	1	16
Fat embolization						2				1			3
Shock							1						1
Anesthetic						1							1
Lower nephron nephrosis	1			2	3	5	1						12
Lower nephron nephrosis with peritonitis				10	3		4				1	1	19
Lower nephron nephrosis and fat embolization						3						1	4
Lower nephron nephrosis and shock						2				1			3
Lower nephron nephrosis and gas infection						1							1
Lower nephron nephrosis and meningitis		1											1
Lower nephron nephrosis and transverse myelitis												1	1
Lower nephron nephrosis and pulmonary					1							1	2
Tetanus						1							1
Arteriovenous fistula						1							1
Laryngeal obstruction												1	1

Source: Autopsy reports from the 406th Medical General Laboratory, Tokyo, Japan.

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TABLE 288.—*Regional frequency of fatal wounds in 1,500 KIA casualties, by anatomic location*

Anatomic location	Number of casualties	Percent of casualties
Head and neck:		
Head	375	25. 0
Neck	60	4. 0
Face	38	2. 5
Total	473	31. 5
Upper extremities:		
Arm and shoulder	56	3. 7
Hand	6	. 4
Total	62	4. 1
Thorax	367	24. 5
Abdomen	143	9. 5
Total	510	34. 0
Lower extremities:		
Leg	39	2. 6
Buttock	13	. 9
Thigh	12	. 8
Hip	6	. 4
Foot	4	. 3
Total	74	5. 0
Multiple wounds, region unknown	381	25. 4
Grand total	1, 500	100. 0

Prisoner-of-War Study

The data in the preceding tables represent the effects of enemy fire. A comparison with the effects of United Nations action against the enemy was made possible through the study of prisoner-of-war casualties made during January 1951 at the 3d and 14th Field Hospitals at Tongnae. Data from 1,000 prisoners were gathered through interrogations of the prisoners via an interpreter. An additional 2,000 medical records of prisoners admitted to these hospitals were analyzed for wound frequency studies, as follows:

	Number of cases
Head and neck:	
Head	53
Face	51
Eye	22
Neck	20
Ear	3
Nose	1
Total	150
Upper extremities:	
Arm	220
Hand	131
Shoulder	78
Forearm	70
Elbow	25
Total	524
Lower extremities:	
Thorax	102
Abdomen	63
Leg	408
Thigh	304
Foot	249
Knee	93
Buttocks	61
Hip	46
Total	1, 326
Grand total	2, 000

The mode of wounding of the 1,000 prisoners of war interrogated revealed the following:

	Number of cases
Casualty-producing agent:	
In ground action:	
Gunshot	430
Shell fragment	235
Grenade	12
Total	677
In air action:	
Bomb	109
Aircraft machinegun	94
Rocket	30
Napalm	44
Total	277
Nonbattle casualties	46
Total	46
Grand total	1, 000

General Observations and Conclusions of Survey Team

From observations and interrogations, this first wound ballistics survey team was able to conclude that the maximum ranges at which wounding occurs are comparatively short. Thus, this team's report states: "Most wounds caused by shell fragments occur within 8 meters of the shell burst. Most wounds caused by small arms occur within 100 meters to 200 meters, rarely beyond 500 meters."

Perhaps the most important of all the conclusions reached by this team concerned the feasibility of body armor. Team members had been impressed by the large number of penetrating wounds in which the missile remained in

the body. They also noted the protective effects of ordinary items of clothing, finding, for example, small arms bullets retained in the foot even when the shot was at very close range, as in self-inflicted wounds. Here the combat shoe seemed to make a considerable reduction in velocity. On the basis of large numbers of this kind of supporting observation, the team was able to conclude:

Whereas most wounds are caused by shell fragments and are of a penetrating rather than a perforating nature, it is believed that some type of body armor is feasible. Requirements for this protective clothing are fundamentally that it be light, flexible, comfortable, be able to screen out missiles with velocities of 1200 ft./sec. or more, and will not handicap combat effectiveness. It is further believed that although the casualty rate per se may not be appreciably reduced, there will be a valuable reduction in the *number* of wounds and in their *severity*. This solves a considerable problem in evacuation, treatment time consumed, and total hospital days. If the chest and abdomen are protected, it may well change many KIA's to WIA's. The problem is not alone that of overall reduction in casualty rate. The psychological effect upon soldiers knowing that they have some protection for vital areas appears obvious, although needing evaluation by field trial.

Although the hospital mortality rate has fallen below 2% and is approaching an irreducible minimum, the killed in action rate and missing in action rate continue quite high. Utilizing publicly released figures, about 14% of the total casualty rate is KIA and approximately a similar percentage exists for missing in action. This means that every fourth casualty is killed or missing. Actually if the 2% hospital mortality rate were added to the KIA and MIA rates, 30% of the total casualties would be KIA, MIA, and wounded died later. It is, therefore, apparent that any further appreciable reduction in casualty rate lies in 1) use of body armor, 2) faster evacuation of casualties from the battlefield. The hazard now of battlefield recovery has not halted the courageous company aid man, but he also becomes a casualty occasionally and replacement in a moment is difficult. The time when he is needed most probably offers the greatest chance for his being wounded. It is believed that body armor for him would aid materially in the performance of his duty.

Recommendations made by the first wound ballistics survey team follow:

1. Attach a Medical Officer to all graves registration units for KIA Survey.
2. Institute exact area frequency for wounds study rather than regional designation; include type wound, severity, disposition.
3. Survey large numbers of WIA and KIA involving thorax and abdominal wounds charting exact area of wound, e.g., ventral, dorsal, flank, and quadrant.
4. Follow carefully 50 casualties involving each anatomic region by means of serial photographs at critical intervals with appropriate surgical notes. This should begin at the Mobile Army Surgical Hospital. The mode/time/distance of evacuation should be included.
5. Field trial of a combination doron and nylon armored vest for Medical personnel in combat units, particularly Medical Company Aid men. If found feasible recommend use for all field troops.
6. Specific orientation of Medical officers in a basic knowledge of wounds, classification, and weapon and missile identification. Medical officers stress the etiology of disease, and many years are spent learning about the varied causative agents. The etiologic agent of a war wound is a missile, and yet with rather rare exceptions members of the medical profession know little about weapons and missile identification. It is no longer adequate for a physician to receive his medical training directed only toward civilian practice, because all doctors now may anticipate military service or the responsibility for civilian populations under the fire of every conceivable weapon.

Since medical officers usually fill in the EMT, and subsequent field records, and since so frequently those doctors are relatively new to the service, a few items are worthy of emphasis and indoctrination:

a. Ask the casualty what hit him. He frequently knows. Specify whether or not he is a battle casualty, has a missile wound or injury, and the actual missile, e.g., small arms (rifle, carbine, Burp, Grease, machinegun), grenade, mortar, artillery, landmine, or shell fragment unknown, etc. Avoid the use of the term shrapnel. Never be content to list just "missile".

b. State whether it was enemy or friendly fire, air or ground.

c. Self-inflicted wounds may be accidental or intentional. If it is known, so state.

d. Describe the treatment given.

e. Record the mode, time, and distance of evacuation.

f. Record disposition and the patient's condition at that time.

Preparation for Field Trial of Body Armor

The first team returned to the United States and prepared its reports in May 1941. The recommendation to The Surgeon General, Department of the Army, for a field trial of an armored vest was readily accepted.

Laboratory tests already completed at that time made it apparent that it would not be possible to defeat most bullets with any reasonable weight of body armor material then available. Within practical ranges, the velocity of bullets is too high. However, it had been found that about 92 percent of the missiles producing WIA casualties were fragments. Of these fragments, 73 percent did not have enough velocity to cause perforating wounds or extensive tissue damage, suggesting that in this important class of wounding missiles the majority were in a lower velocity, lower energy range. It was assumed that a large number of these could be defeated by an armor which would stop fragments having velocities of 1,200 f.p.s. or lower. It was immediately apparent that steel could not be incorporated into any type of thoracoabdominal protective clothing with any degree of success because of its lack of flexibility and excessive weight. Aluminum proved to have a relatively low ballistic limit. It was not flexible and would have proved difficult to tailor into a protective vest. Nylon cloth (12 layers of 2 x 2 basket weave) was found to have a ballistic limit of 1,275 f.p.s. against a 17-grain simulated fragment, and its great flexibility was thought to offer most feasibility for fabrication into a protective vest. Doron (multiple layers of fiber-glass cloth laminated by a methacrylate resin) also proved highly effective in defeating these simulated fragments. Doron surpassed nylon in performance when struck by the .45 caliber pistol ball but lacked the flexibility of nylon. Doron could, however, be molded to conform to the contours of the body.

The Naval Field Medical Research Laboratory at Camp Lejeune, N.C., had for some time been working on the development of a slipover type of vest, using doron armor. That installation had pioneered the use of curved doron

plates in body armor and had established the fact that the ballistic properties of doron were unaffected by the manufacturing process. Models of such a vest were in existence, and the Naval Field Medical Research Laboratory possessed necessary experimental tailoring facilities to make models of various designs. Accordingly, members of the first survey team met with personnel at Camp Lejeune, and it was agreed to incorporate into the vest certain modifications suggested by the Korean battle casualty survey experiences. The most significant contribution was the addition of 12 layers of nylon to the area covering the shoulder girdle. The modified vest (figs. 340 and 341) was described as follows:[7]

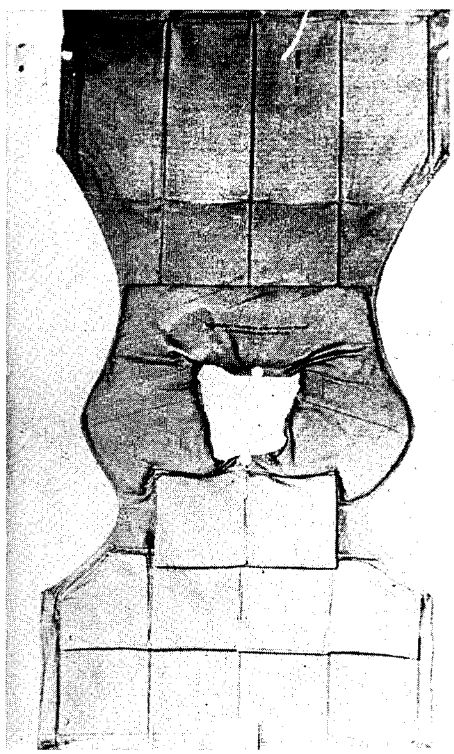

FIGURE 340.—Slipover thoracoabdominal vest with nylon shoulder girdle and 16 doron plates. Field tested, 14 June to 13 October 1951.

A slipover, semi-flexible thoraco-abdominal vest weighing 6.1 lb. made of 2 x 2 basket weave nylon covering the upper chest and shoulder girdle, and a lower portion made of 16 curved doron plates covering the lower chest and upper abdomen. Ballistic properties as follows: Capable of stopping a .45 caliber pistol or Thompson submachine gun bullet at the muzzle; all the fragments of the U.S.A. hand grenade at three feet; 75% of the fragments of the U.S.A. 81 mm. mortar at ten feet; and the full thrust of an American bayonet.

[7] Medical Project—Body Armor, Korea, 14 June to 13 October 1951, issued by Joint Army-Navy Mission, Medical Research and Development.

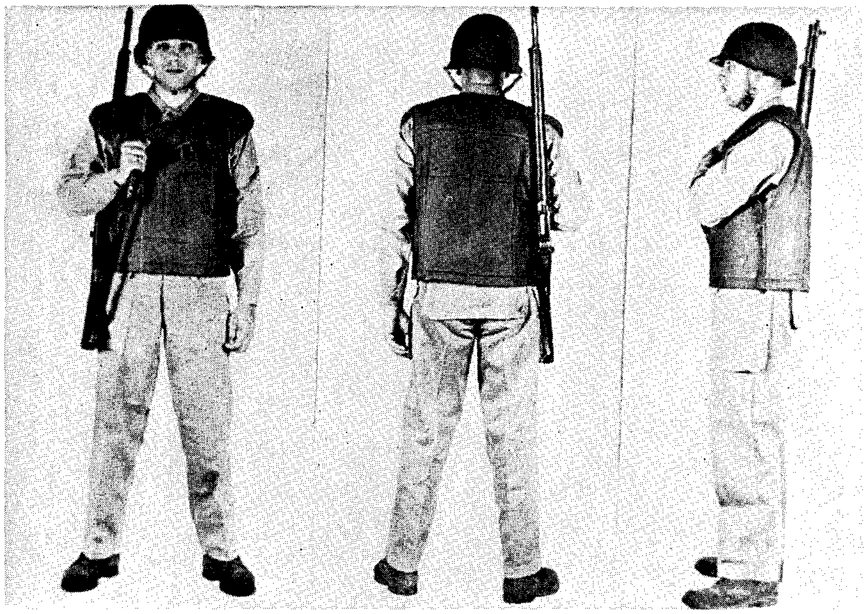

FIGURE 341.—Three views of doron slipover vest on soldier.

In June 1951, 50 such vests were fabricated at the Naval Field Medical Research Laboratory, partially aided by funds allocated by the Army Quartermaster Corps.

JOINT ARMY-NAVY BODY ARMOR FIELD TEST, 14 JUNE–13 OCTOBER 1951

Upon invitation by Colonel Wood to Adm. Herbert L. Pugh, Chief of the Bureau of Medicine and Surgery, Department of the Navy, a joint Army-Navy medical mission was organized and dispatched to the Far East Command on 14 June 1951 for the purpose of field testing, under actual combat conditions in Korea, an item of equipment designed as body armor for protection of the chest, the shoulders, and the abdomen. Officer members of the team were (Army) Colonel Holmes, Captain Phillips, Lieutenant Coe, (Navy) Comdr. John S. Cowan, MC, and Lt. Comdr. Frederick J. Lewis, Jr., MSC.

Upon arrival in Tokyo, the unit was attached to the 406th Medical General Laboratory for logistical and administrative support. After drawing the necessary equipment and supplies, the team departed for Korea, arriving at Headquarters, 5th Regiment, 1st Marine Division, on 4 July 1951.

The specific mission at this time was to (1) determine and evaluate the reaction under combat conditions of Medical Department personnel, particularly company aidmen, to the proposal of wearing body armor, and (2) determine and evaluate the reaction under combat conditions of personnel of the

various services to the proposal of wearing body armor. During the course of the following 2 months, these 50 vests were worn by approximately 6,000 soldiers and marines. Tests were performed with the 5th Marine Regiment and the 23d and 38th Infantry Regiments of the 2d Division.

Conclusions of Body Armor Test Team

The conclusions reached by this team were as follows:

1. That body armor or protective clothing of some type for the vital anatomic areas is almost unanimously desired by all combat troops, particularly the combat veteran after several actual fire fights with the enemy.
2. That the body armor vest was received quite favorably by most Commanding Officers, who were eager for its trial, feeling that the psychological effect upon the troops would be of considerable morale value.
3. That the troops of all arms and services were completely cooperative and constructive in their trial of the body armor, appearing to sense the responsibility of their judgment upon an item of equipment designed to save their lives as well as others.
4. That thorough indoctrination of all troops should precede the wearing of any body armor. Such indoctrination should include familiarity with percentage relationships of the various wounding agents, the anatomic distribution of hits, and the most commom lethal wounds. The protective ballistic properties of the body armor should be thoroughly demonstrated.
5. That the body armor vest, which weighed 6.1 lb., was not considered an excessive weight, and that such a weight per se did not hinder or handicap the wearer.
6. That the weight of the body armor was tolerated and carried easily because of its proper distribution and suspension from the entire shoulder girdle.
7. That such body armor (6.1 lb.) could be and was worn over mountainous terrain of extremely rugged nature in a hot, humid climate, with only a few adverse complaints of the weight factor from the men.
8. That such body armor, in the Korean summer, received its severest criticism as being excessively hot.
9. That a water-proof or water-resistant covering fabric should be used to prevent gain in weight from perspiration or rain. Gain in weight due to such reasons was 1½ to 2 lb. for the armored vest tested.
10. That such armor should be utilized as organizational equipment rather than individual equipment, and as such should be transported via organizational vehicles to the closest possible point of enemy contact.
11. That tests of body armor are far more significant when done under combat conditions than when performed under training or simulated combat conditions.

ARMY BODY ARMOR TEST TEAM, FEBRUARY–JULY 1952

Upon returning to the United States in September 1951, the team recommended that approximately 1,400 vests incorporating those changes suggested by the field test in Korea be further tested in actual combat in order to determine the effectiveness of the vest in defeating missiles from enemy weapons. Accordingly, the Army developed a model (fig. 342) made of 12 plies of 2 x 2 basket weave nylon weighing 13 ounces per square yard. The layers of nylon were triangularly spot bonded together. The Marine Corps realized that expediency was of paramount importance and developed a design based upon

SC 400857, 400858

FIGURE 342.—Army all-nylon vest, T52–1. One of prototypes tested in the period from 1 March to 15 July 1952. A. Front view. B. Rear view.

doron-nylon combination and proceeded to its standardization by 16 November 1951. The Army all-nylon vest was covered with a vinyl-coated nylon poncho material, olive drab in color, with a one-quarter inch layer of sponge rubber beneath the covering over the ribs and the shoulder girdle. The sponge rubber provided an offset of the vest away from the body since it was felt that contusions or fractures might result from impact of nonpenetrating missiles upon the vest. The vest was provided with two rectangular gusset-type pockets closed by a triangular flap and a snap fastener. The frontal closure was effected by means of three dot-type fasteners. Loops or straps of nylon were provided, two front and two back, for supporting cartridge and pistol belts. The vest was fabricated in two sizes as follows:

1. Size 42; area of protection, 6.7 square feet; weight, 7 pounds and 12 ounces.

2. Size 46; area of protection, 7.4 square feet; weight, 8 pounds and 4 ounces.

On 18 February 1952, an Army body armor team departed for Korea with the following objectives:

1. To determine the relative effectiveness of the various body armor prototypes against various types of enemy fire, delivered under a variety of environmental and tactical situations.

2. To determine the dimensions of soldier acceptance and use of body armor.

3. To determine the most satisfactory methodology to orient soldiers in the use of body armor.

4. To determine the relative reduction in wound incidence, extent, and severity in soldiers wearing body armor.

At this time, the team consisted of officers representing the Medical Corps, the Army Field Forces, the Ordnance Corps, and the Quartermaster Corps.

During the course of the test in Korea, the team numbered 24 officers and 33 enlisted men. Initially, the team was directed by Lt. Col. Andrew A. Aines, QMC; later, Lt. Col. William W. Cox, MC, assumed the role of team commander.[8]

Special equipment which was not available in the theater was obtained in the Zone of Interior and accompanied the test team to Korea. These items

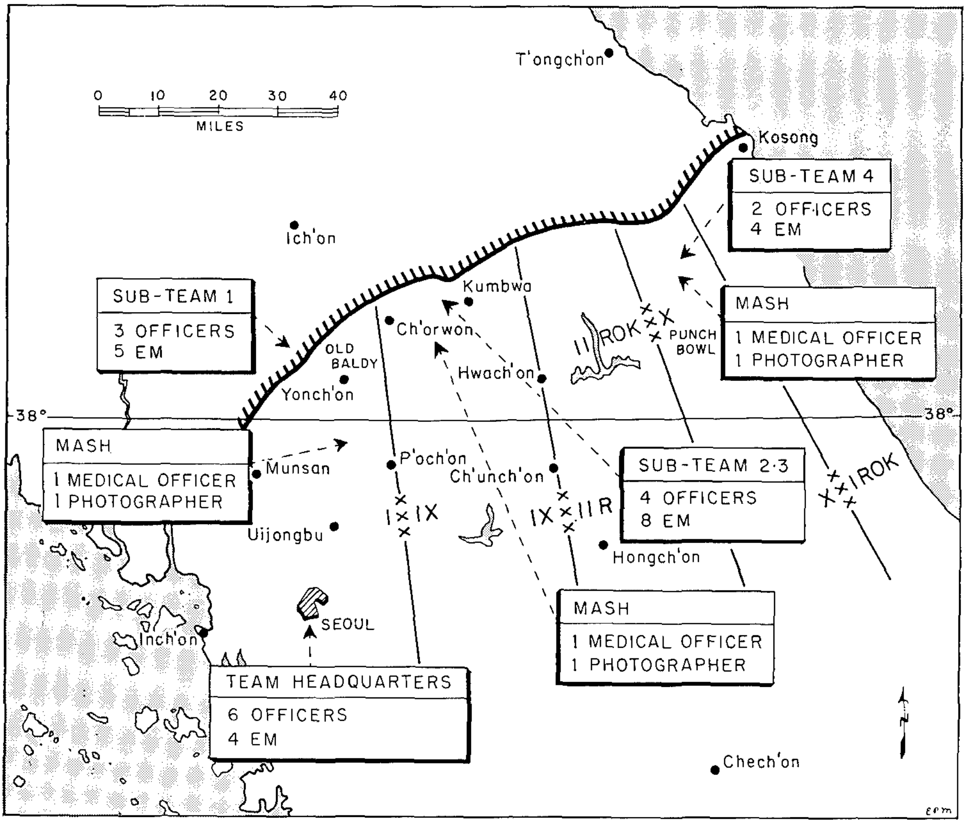

FIGURE 343.—Map showing disposition of Body Armor Test Team, March–July 1952.

[8] Additional officer personnel serving with the Body Armor Test Team were as follows:

On TDY from the Zone of Interior to Korea: Maj. Henry F. Breezley, OrdC, Development and Proof Services, Aberdeen Proving Ground, Md.; Maj. William F. Enos, MC, Armed Forces Institute of Pathology, Washington, D.C.; Maj. John W. Irving, QMC, Quartermaster Board, Capt. William H. Bailey, MC, HQ, Army Chemical Center, Md.; Capt. William L. Camper, Inf., Army Field Forces Board No. 3, Fort Benning, Ga., Capt. Anthony J. Daniels, QMC, Quartermaster Board; Capt. John M. Nowell, MSC, Walter Reed Army Medical Center, Washington, D.C.; Capt. Mack Strauss, QMC, HQ, Fort Lee, Va.; and Lt. Richard B. Stoughton, MC, HQ, Army Chemical Center.

Detailed from Eighth U.S. Army units in Korea: Maj. Rodney O. Capps, QMC, 23d QM Group; Capt. William Barber, QMC, 23d QM Group; Capt. Robert H. Bessey, Jr., Inf., 15th Infantry; Capt. Henry E. Davis, QMC, 23d QM Group; Capt. Gene P. Eardley, MC, 25th Evacuation Hospital; Capt. Richard W. J. Fasey, Inf., 32d Infantry; Capt. Ellwood R. Lambert, Inf., 15th Infantry; Capt. Robert L. Mignery, QMC, 23d QM Group; Capt. Leonard K. Pierce, QMC, 23d QM Group; Capt. Donald C. Tanner, MC, 25th Evacuation Hospital; 1st Lt. Gilbert D. Cheney, Inf., 32d Infantry; 1st Lt. William B. Gillett, Inf., 233d Infantry; and 2d Lt. Rodney M. Brigg, Inf., 160th Infantry.

included photographic equipment, weather recording equipment, tape recorders, instruments for ballistics studies, and other miscellaneous expendables. All other classes of supplies and equipment were obtained from theater stocks. These were requisitioned by, and assembled at, team headquarters in Seoul. From this point, they were issued to subteams operating in forward areas (fig. 343). Each subteam was self-sufficient for supply, administration, and operation. Except for rations and petroleum products, no supply burden was imposed on units participating in the tests. Because of the magnitude of the test, the team was not attached to the theater medical general laboratory but operated as an independent unit assigned to Headquarters, Eighth U.S. Army, Korea.

Conduct of Test, 1 March Through 15 July 1952

During the course of the test, the Army nylon vest was worn by over 15,000 soldiers for an aggregate of approximately 400,000 man-hours. The Eighth U.S. Army organizations which participated in the test are shown in table 290. In addition, other United Nations troops using vests on a limited distribution were (1) Philippine forces attached to I Corps, 3d Division, 7th Regiment; (2) ROK (Republic of Korea) troops of the 1st ROK Division, attached to I Corps, 11th Regiment; (3) Ethiopian forces attached to IX Corps, 2d Division, 23d Regiment; (4) Colombian forces attached to IX Corps, 7th Division, 31st Regiment; and (5) French Forces attached to IX Corps, 2d

TABLE 290.—*Eighth U.S. Army units participating in test of Army nylon vest*

Unit			Date entered	Date terminated
Corps	Division	Regiment		
			1952	*1952*
I	3d	7th	1 Mar	25 Apr
I	3d	15th	29 Mar	25 Apr
I	3d	65th	13 Apr	25 Apr
I	45th	179th	1 May	15 Jul
I	45th	180th	1 Jun	15 Jul
I	45th	279th	1 May	31 May
IX	2d	23d	9 Apr	25 Apr
IX	2d	38th	30 Mar	13 Apr
IX	7th	17th	7 May	15 Jul
IX	7th	31st	7 May	15 Jul
IX	7th	32d	16 Apr	15 Jul
IX	40th	160th	4 Jun	30 Jun
IX	40th	223d	4 Jun	30 Jun
IX	40th	224th	4 Jun	30 Jun
X	25th	14th	2 May	10 Jun
X	25th	27th	18 Apr	10 Jun
X	25th	35th	18 Apr	2 May

Division, 23d Regiment. Other personnel using vests on special studies were pilots serving I Corps; pilots of helicopter detachments serving the 8063d, 8076th, and 8209th Mobile Army Surgical Hospitals; and the 3d Air-Sea Rescue Squadron.

In this period, there were 2,099 battle casualties and 322 soldiers killed in action in the divisions in which body armor was used. It must be emphasized that the total body armor available to division personnel was exceedingly small, averaging about 350 vests per division during the period of the test. A total of 1,400 vests were available during the test period and these were received by the team from the Zone of Interior as follows (48 vests accompanied the initial team members):

1952	*Number of vests*
Feb. 18	48
Mar. 6	50
26	200
Apr. 10	200
13	200
21	200
24	200
May 4	200
8	102
Total	1, 400

Wound Ballistic Studies on WIA Casualties

A total of 1,591 wound ballistic studies, in many instances including pictures and X-rays, were made on soldiers from all of the American divisions on the frontline. These studies included battle casualties, accidental wounds, and self-inflicted wounds. Table 291 lists the regional distribution of wounds in 908 WIA casualties not wearing body armor.

In the group of WIA casualties who were not wearing body armor, there were 278 wounds in the region of the body (chest and upper part of the back) that would have been covered by the vests. An estimate of the effect of the vest, had it been worn, is that it would have probably prevented the wound in 204 (73.4 percent) cases; might possibly have prevented the wound in 17 (6.1 percent); been of questionable value in 27 (9.7 percent); and would have had no effect in 30 (10.8 percent).

A total of 552 soldiers were wounded in action while wearing body armor (table 292).

A breakdown of 1,460 battle casualties who were studied during the test period by causative agents and by type of wounding (that is, multiple or single) is shown in tables 293 and 294, respectively. Typical fragments and missiles removed from the casualties are shown in figure 344.

TABLE 291.—*Regional distribution of 1,474 wounds in 908 WIA casualties not wearing body armor*

Body region	Number of wounds	Percent of total wounds
Head	208	14. 1
Neck	48	3. 2
Chest	167	11. 3
Back:		
Upper part	111	7. 5
Lower part	103	7. 0
Abdomen	60	4. 1
Extremity:		
Upper	359	24. 4
Lower	408	27. 7
Genitalia	10	. 7
Total	1, 474	100. 0

TABLE 292.—*Regional distribution of 850 wounds in 552 WIA casualties wearing body armor*

Body region	Number of wounds	Percent of total wounds
Head	121	14. 2
Neck	23	2. 7
Chest	40	4. 7
Back:		
Upper part	34	4. 0
Lower part	78	9. 2
Abdomen	14	1. 6
Extremity:		
Lower	294	34. 6
Upper	241	28. 4
Genitalia	5	. 6
Total	850	100. 0

A further breakdown of the fragments that caused these wounds is as follows:

	Percent
Mortar	38. 6
Grenade	24. 0
Artillery	16. 2
Mine	9. 5
Undetermined	11. 7

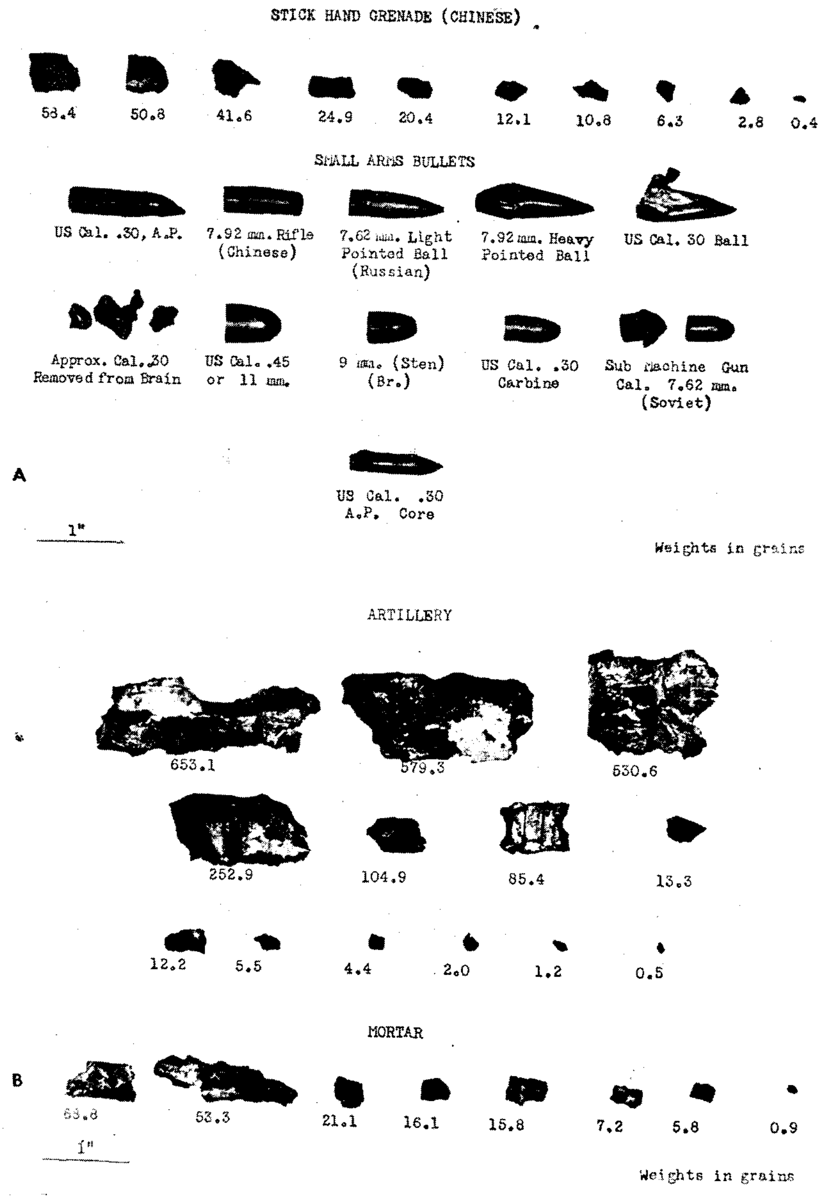

FIGURE 344.—Typical fragments and missiles removed from casualties in Korea. A. Stick hand grenades (Chinese) and small arms bullets. B. Artillery and mortar. C. Secondary missiles.

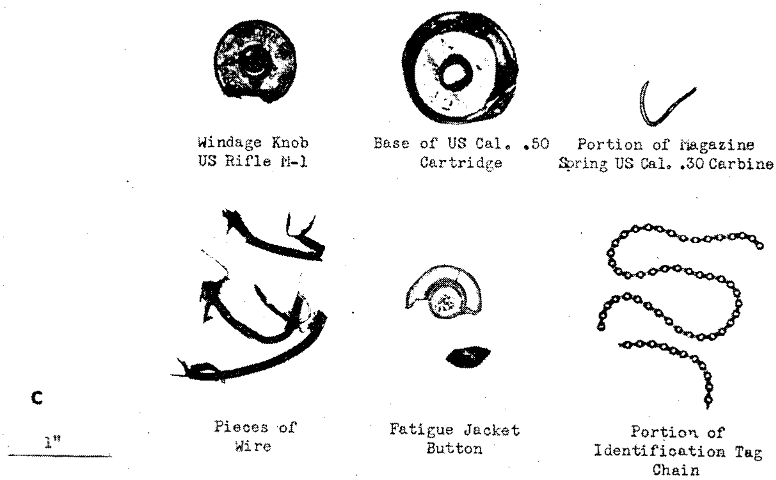

FIGURE 344.—Continued.

TABLE 293.—*Distribution of 1,460 armored and unarmored WIA casualties, by causative agent*

Causative agent	Armored casualties		Unarmored casualties		Total casualties	
	Number	Percent	Number	Percent	Number	Percent
Shell fragment	467	84. 6	769	84. 7	1, 236	84. 7
Small arms	85	15. 4	139	15. 3	223	15. 3
Total	552	100. 0	908	100. 0	1, 459	100. 0

TABLE 294.—*Distribution of 1,460 armored and unarmored WIA casualties, by type of wounding*

Type of wounding	Armored casualties		Unarmored casualties		Total casualties	
	Number	Percent	Number	Percent	Number	Percent
Single wounds	326	59. 0	485	53. 4	811	55. 5
Multiple wounds	226	41. 0	423	46. 6	649	44. 5
Total	552	100. 0	908	100. 0	1, 460	100. 0

The character of the wounding agent in the 1,460 WIA casualties indicates that the type of fire to which the vest and nonvest wearers were exposed was in general the same and thus can not account for the observed difference in the wound distribution.

Studies on KIA Casualties

During the period of the test, 547 post mortem examinations were made on soldiers from American divisions along the frontline who had been killed in action. The wounding agent was determined in 415 cases of the 547 post mortem examinations that were made (table 295). The regional frequency of the wounds and their relationship to the cause of death is shown in table 296.

A study was made of the chest wounds in this group of 547 KIA casualties,

TABLE 295.—*Distribution of 415 KIA casualties, by wounding agent*

Wounding agent	Number of casualties	Percent of casualties
Shell fragments	278	67. 0
Small arms	106	25. 5
Mines	25	6. 0
Blast and burns	6	1. 5
Total	415	100. 0

TABLE 296.—*Regional frequency of lethal and associated wounds in 547 KIA casualties, by anatomic location*

Anatomic location	Lethal wounds		Associated wounds	Regional total		Percent regional wounds fatal
	Number	Percent		Number	Percent	
Head	221	40. 4	28	249	23. 8	88. 7
Neck	23	4. 2	42	65	6. 2	35. 4
Chest	154	28. 1	72	226	21. 6	68. 1
Back:						
Upper part	37	6. 8	27	64	6. 1	57. 8
Lower part	17	3. 1	35	52	5. 0	32. 7
Abdomen	35	6. 4	31	66	6. 3	53. 0
Extremities:						
Upper	9	1. 6	138	147	14. 0	6. 1
Lower	38	7. 0	138	176	16. 8	21. 6
Genitalia	-------	-------	2	2	. 2	-------
Miscellaneous	13	2. 4	-------	-------	-------	-------
Total	547	100. 0	513	1, 047	100. 0	

and an estimate (using the previously described criteria) of the possible beneficial effect of the vest was determined, as follows: For the total 226 chest wounds, the vest would have prevented a lethal wound in 61 (31.9 percent) of the primary chest wounds and 24 (24.2 percent) of the associate wounds; would probably have reduced the severity of the wound in 47 (24.6 percent) of the primary wounds and 24 (24.2 percent) of the associate wounds; and in 58 (30.4 percent) of the primary and 12 (12.2 percent) of the associate wounds would have been of questionable value.

These studies indicate that 30 to 40 percent of the fatal chest wounds incurred by soldiers in combat would have been prevented by the use of body armor. From another point of view, this seems to indicate that 10 to 20 percent of the soldiers who were killed in action would have survived if they had worn body armor. The effectiveness of the vest in preventing chest wounds in the KIA casualties was not so marked as in the WIA casualties. One explanation of this disparity lies in the higher incidence of small arms wounds in the KIA (approximately 25 percent) as compared to the WIA casualties (approximately 15 percent).

Study of Vests Used in Test

During the test, 254 vests were recovered which were hit (fig. 345) while worn by soldiers in combat. A study revealed that of the group of soldiers

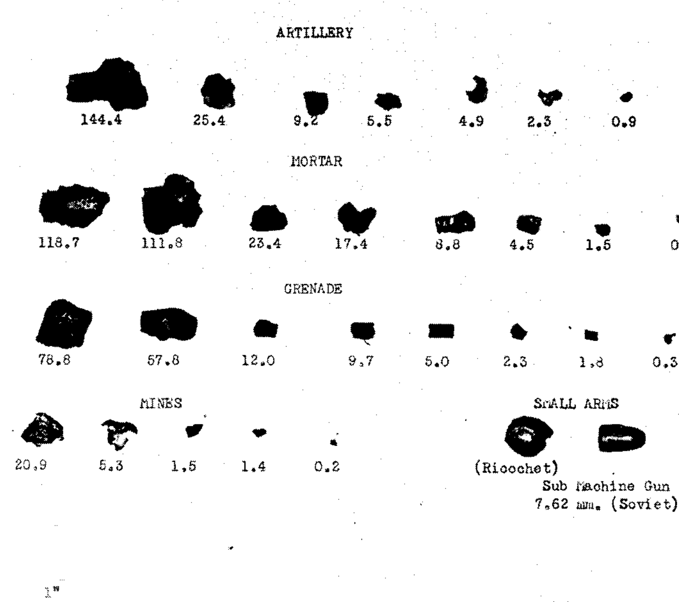

FIGURE 345.—Typical missiles removed from vest, armor, T52–1, in Korea.

wearing the vests, 52 (20.5 percent) were returned to duty, 128 (50.4 percent) were evacuated because of wounds, 55 (21.6 percent) were killed in action, and in 19 (7.5 percent) the disposition of the soldier was unknown. Of the 128 soldiers who were evacuated, 35 (27.3 percent) sustained wounds through the vest.

Of the 55 who were killed in action, 24 (43.6 percent) were killed by wounds through the vests, and 31 (56.4 percent) were killed by wounds in areas that were not covered by the vest. The wound-missile ratio on these groups is shown in table 297. In evaluating these figures it should be borne in mind that approximately 85 percent of wounds were due to fragments which accounts for the apparent ineffectiveness of the vest against fragmentation.

TABLE 297.—*Causative agent and disposition of 254 vest-wearing KIA (55) and WIA (199) casualties*

Disposition	Wound through vest		Wound not through vest		Total casualties	
	Number	Percent [1]	Number	Percent [1]	Number	Percent [1]
	Small arms					
Wounded in action:						
Returned to duty					7	13. 5
Evacuated	15	42. 9	16	17. 2	31	24. 2
Killed in action	14	58. 3	14	45. 2	28	50. 9
Unknown					1	5. 3
Total	29	49. 2	30	24. 1	67	26. 4
	Shell fragments					
Wounded in action:						
Returned to duty					45	86. 5
Evacuated	20	57. 1	77	82. 8	97	74. 8
Killed in action	10	41. 7	17	54. 8	27	49. 1
Unknown					18	94. 7
Total	30	50. 8	94	75. 9	187	73. 6
Grand Total	59	100. 0	124	100. 0	254	100. 0

[1] Percent for dichotomy small arms versus shell fragments.

Among the 254 vests which sustained hits and were available for study, complete information regarding the type of wound and the disposition of the

casualty was collected in 235 cases. These latter cases were studied and broken down in the following categories:

	Number of cases	*Percent of total*
1. Missiles which did not perforate the vest and which caused no abrasion or contusion of the underlying area	101	42. 9
2. Missiles which did not perforate the vest but which caused an abrasion or contusion of the underlying area	23	9. 8
3. Missiles which perforated the vest but which did not enter the body	30	12. 9
4. Missiles which perforated the vest and entered the body only a short distance; that is, subcutaneously	22	9. 3
5. Missiles which perforated the vest and penetrated into one of the major body cavities or organs	20	8. 5
6. Missiles which perforated the vest and which perforated the body or which resulted in death	39	16. 6
Total	235	100. 0

In categories 1, 2, and 3 are classified those missile hits which were completely defeated by the body armor. Wounds with a reduction in expected severity are seen in category 4. In category 5, the wounds are severe but would have been even more severe or fatal if body armor had not been worn. In category 6 are placed those wounds in which there has been little, if any, change in wound severity due to the wearing of body armor.

The penetrations as compared to the perforations of the vests, resulting from all missile hits, are shown in table 298.

TABLE 298.—*Distribution of 874 hits on 254 armor vests, by causative agent*

Causative agent	Vests hit		Penetrating hits [1]		Perforating hits [2]	
	Number	Percent	Number	Percent	Number	Percent
Small arms	63	24. 8	30	24. 4	93	75. 6
Shell fragments	184	72. 4	549	75. 7	176	24. 3
Unidentified	7	2. 8	14	53. 8	12	46. 2
Total	254	100. 0	593	67. 9	281	32. 1

[1] Missiles were defeated by vest, and no wound was produced.
[2] Missiles succeeded in perforating vest and in producing a wound.

From the tabulation presented for the 235 casualties, the figures indicate that wounds of the anterior and posterior aspects of the chest and of the upper quadrant of the abdomen were prevented (fig. 346) in 154 (65.6 percent) of the casualties. There were 81 (34.4 percent) casualties who sustained wounds through the region covered by the vest (fig. 347), and within this group there

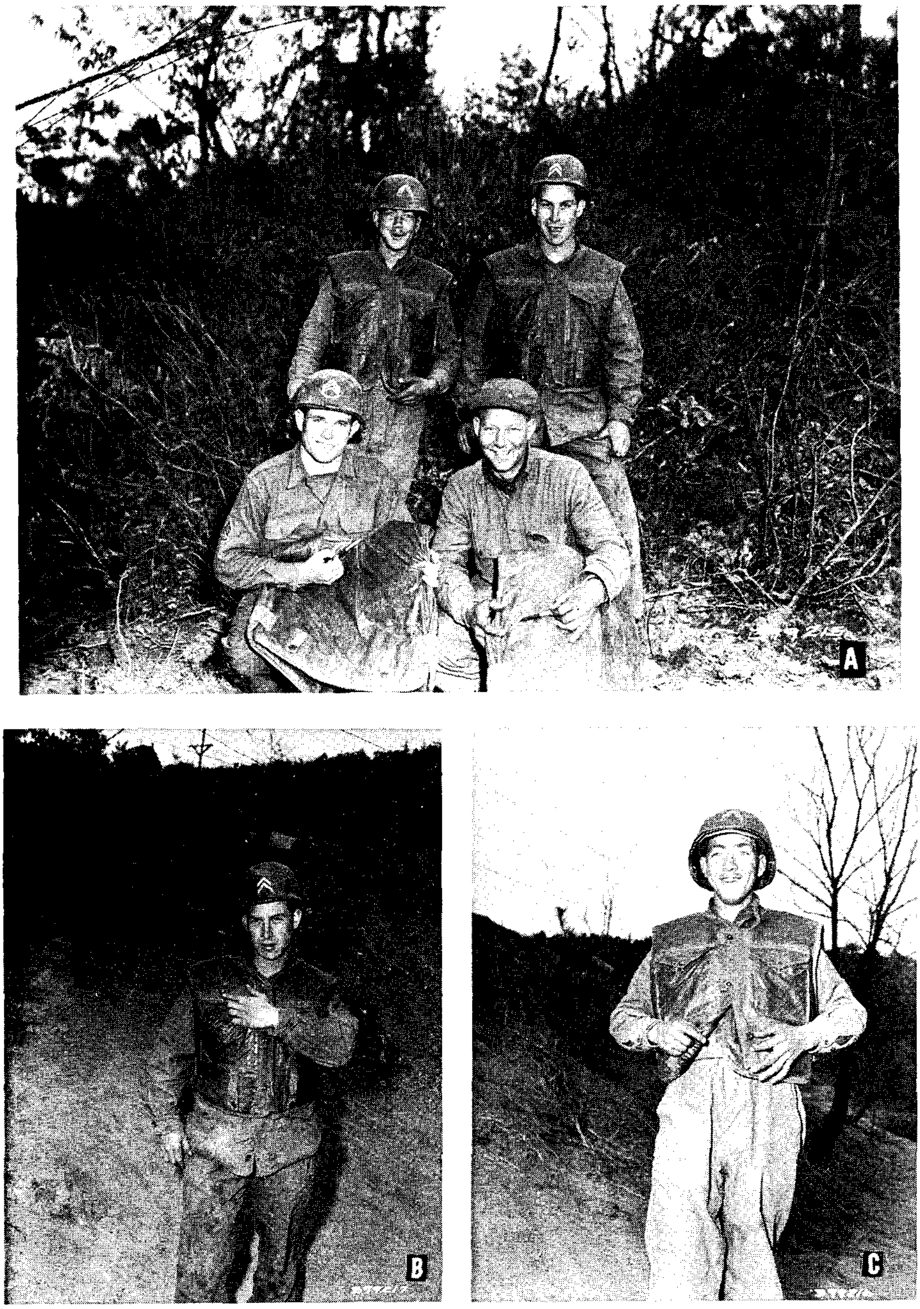

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FIGURE 346.—Protection provided by the Army all-nylon vest, T52–1. A. Four soldiers of Company K, 15th Infantry Regiment, 3d U.S. Infantry Division, whc were protected from shell fragments which struck but did not perforate the armor. B. and C. Closeups of two of the vests shown in A.

SC 409560

FIGURE 347.—Lt. Rodney M. Brigg, Body Armor Team (right), points to skin bruise on back of Lt. Frank H. Bassett, Company G, 160th Infantry Regiment, 40th Infantry Division. The vest defeated two hand grenade fragments.

was definite evidence that the severity of the wound had been reduced in 22 (27.2 percent) of the cases, that it was difficult to state whether the vest had an effect on the severity of the wound in 20 (24.7 percent) cases, and that there was no evidence that the vest reduced the severity of the wound in 39 (48.1 percent) cases. In these 39 cases, 24 (61.5 percent) casualties were killed by the missiles which perforated the vest.

Conclusions of Body Armor Team

The body armor team reported [9] its conclusions under the conditions of the test as follows:

a. The Armor, Vest, Nylon T–52–1, is much more effective against fragment type missiles than small arms missiles. During the test period 67.9% of all type missiles hitting the armor were defeated. 75.7% of all fragments were defeated and 24.4% of all small arm missiles were defeated.

b. This prototype was acceptable to the majority of soldiers who wore it in combat. The extent of acceptability was, in addition to many other factors, influenced by the unique

[9] Cox, W. W., Irving, J. W., Breezley, H. F., and Camper, W. L.: Report on the Use of Body Armor in Combat—Korea, February 1952-July 1952. Issued by the Office of the Assistant Chief of Staff, G-4 Logistics, September 1952.

character of the Korean campaign. A desire for body armor was evident early in the test period, and this prototype was the most suitable armor of its nature available to satisfy this demand. Acceptance was invariable, often qualified with suggestions for improvements.

c. Of the methods used to orient troops in the use of Nylon Armor, the best results were obtained by orienting company sized groups in reserve areas. This may not be the most suitable method of orientation for the Army as a whole, as selection of methods was determined by conditions existing in Korea.

d. The Armor, Vest, Nylon T–52–1 worn by soldiers in combat during the test period, reduced the incidence of chest and upper abdominal wounds by 60 to 70%. It is estimated that 25 to 35% of the chest and upper abdominal wounds sustained by combat soldiers wearing the armor during this test period were reduced in severity.

The team also considered the psychological effects and stated:

a. Research of body armor would be incomplete without an understanding of the psychological structure of body armor use and requirements. Factors to be considered are legion, but some of the most important are motivation, the effect on confidence, the effect on aggressiveness, the effect on morale, and finally the acceptance by the soldier.

b. The use of body armor is motivated by one of the most powerful impulses in our psychological makeup, i.e., the desire to survive. In the heat of actual combat, soldiers have reported later, time and again, that they rarely notice the weight and bulkiness of the vests (fig. 348). In these tense periods it seems that the desire for protection outweighs the

FIGURE 348.—Effect of armor on evaporation of perspiration. Subjects wore armor for 30 minutes at temperature of 90° F. When soldiers were under enemy fire, they did not complain of the excessive perspiration.

physiological deficit resulting from the added burden. On the other hand, interviews with soldiers returning from patrols which had no fire fights or skirmishes with the enemy, indicate that the men are less disposed to wearing body armor and are more critical of its weight and limitation of mobility.

c. The action in Korea is unique in our military history in that the lack of specific battle goals and the prolonged truce talks resulted in a feeling of caution in all combat echelons. Commanders, under these conditions, are not quite so ready to sacrifice personnel on the battlefield. This lack of an overpowering motivation may have an important bearing on the seemingly widespread acceptance and desire for body armor on the part of the troops and their commanders. This unique situation suggests, too, the possibility that the need for body armor by our soldiers in Korea is accentuated if they are to fight with their usual verve and aggressiveness.

d. The effect of body armor on confidence is probably best expressed in the results of the post-use interviews where over 85 percent of the men stated that they felt safer and more confident when wearing body armor. This feeling of increased safety and assurance is undoubtedly of paramount importance in explaining the widespread acceptability of body armor in combat.

e. Interviews with commanders, who have led troops wearing body armor in combat, have repeatedly emphasized that aggressiveness is increased and that there is more of a desire and willingness to engage the enemy at close quarters. Since one of the great deterrents to aggressiveness in combat is fear of being wounded or killed, it would seem that the feeling of increased safety and confidence, in part at least, accounts for the increased aggressiveness noted by the troop commanders.

f. A poll of over 100 front line physicians and surgeons has resulted in the almost unanimous expression of opinion that the use of body armor would result in an increase in morale among combat troops. The measurement of morale is difficult and varies with many factors which cannot be controlled while another unknown factor is being tested. In spite of the rather poor motivation for combat during the period of test, the morale of the troops was generally good, and the test team members were unable to detect any changes in morale in the units that were using body armor. It is rational to conjecture, however, that the morale of our troops would be elevated as long as they possessed an item which would give them superiority over the enemy and thus diminish their chances of being wounded or killed. It would seem that if, and when, the enemy develops a similar vest or devises effective countermeasures to our vest, that the effect of the vest on morale would then be negligible.

g. Under certain conditions the effect of body armor on morale may not be good. For example, during the last month of the test period there were several instances where soldiers who had previously used body armor expressed a reluctance to their unit leaders to go out on patrols when body armor was not available. These instances were precipitated by the fact that there was not enough of the item to go around or that the vests had been moved to other sectors or units for more favorable testing. In any situation where the troops had previously used body armor and for some reason it became limited in supply or not available, it is conceivable that the effect on morale would be very unfavorable.

h. If the willingness or lack of willingness on the part of troop commanders and their troops to return body armor to the test team officers after use may be used as an index of acceptability, then there is no doubt that the test item is almost universally approved of. Many times, especially during the last period of the test and in areas where there was a lot of action, it was difficult for the test team officers to tactfully get the troop commanders and the troops to release their physical possession of the armor when it became necessary to shift the vest to other personnel. There seems to be no doubt that the desire for protection in the minds of the men is utmost, and outweighs the physiological handicaps imposed by the added weight and bulkiness.

i. This is well illustrated by an action of the 45th Division in securing a hill in advance of the MLR. The action which lasted for several weeks was extremely heavy and the casualties were high. Demand for the vest became so acute that the test team members

lost control of the vest study. Because of the limited quantity of vests available there were not enough to equip each soldier with one. Soldiers who were wearing the vests and who were wounded were frequently relieved on the battlefield of their armor by other soldiers who did not have vests. The vests that reached the forward aid station were usually taken away by the combat troops before the test team members had an opportunity to study them. In addition there were several instances where soldiers would be wearing vests in the usual manner and then in addition have other vests wrapped about the lower abdomen, groin, and thighs. Other instances were reported in which an additional vest was fitted in some fashion about the face and head.

j. Many factors have been discussed previously as to why the soldiers in Korea have accepted body armor so wholeheartedly. One final feature to be considered in regard to acceptance is the factor of initial contact with any new item (body armor). To what extent is this acceptance colored by a fad-like reaction because of the newness, the exclusiveness, the widespread publicity and the fashionability? Only time will tell. It is of interest to note, however, that prior to the arrival of the Body Armor Team in Korea, several thousand of the earlier M12 type body armor vests (figs. 349 and 350) were in supply rooms and were infrequently used. After the team had been in Korea for several months with its attendant publicity and information campaign, body armor of any type was at a premium (fig. 351) and was difficult to supply in sufficient quantities (fig. 352). Even the supply of M12's, which heretofore had not been in demand, was rapidly exhausted (fig. 353).

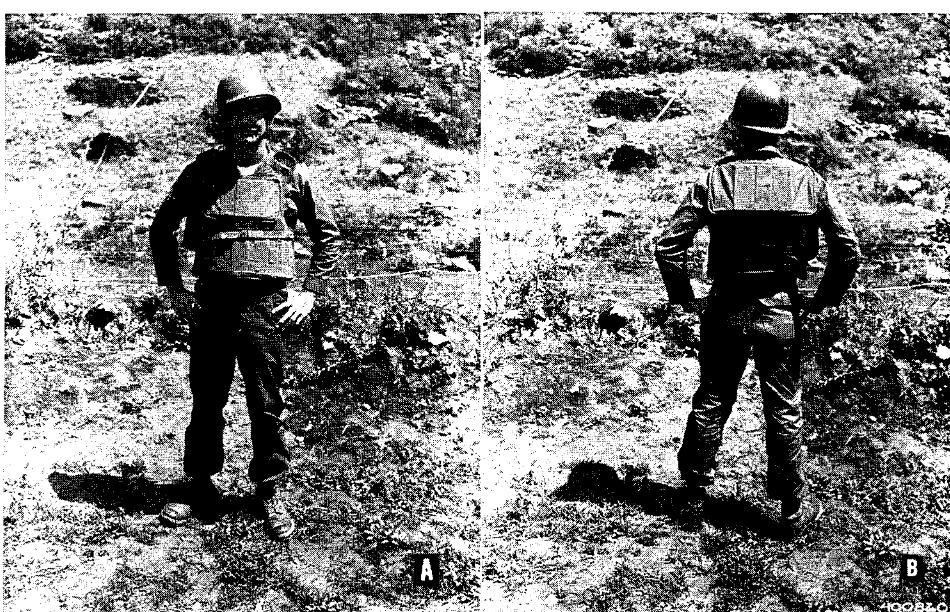

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FIGURE 349.—World War II M12 vest with aluminum plates and a nylon cloth backing, Korea, 25 May 1952. A. Front view. B. Back view.

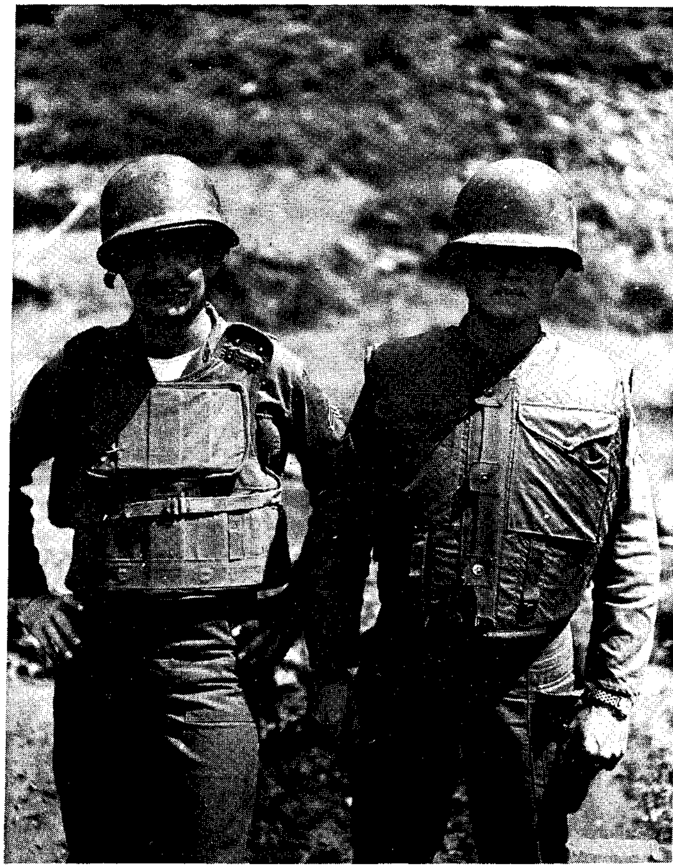

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FIGURE 350.—Front views of World War II M12 vest (left) and all-nylon T52–1 vest. Note increased body coverage with newer armor vest. Korea, 25 May 1952.

Recommendations of Body Armor Team

Recommendations based on findings submitted by the team were as follows:

a. That continuing study be conducted in the development of body armor materials to obtain the optimum in protection versus weight, with thought toward a material that will stop light, medium velocity sub-machine gun bullets, as well as fragments, and to improve the comfort and utility value.

b. That logistical problems in supplying the body armor to troops be studied.

c. That additional testing be conducted under controlled conditions for improving functional suitability and compatibility with other clothing and equipment.

d. That the use of body armor as an item of clothing be thoroughly explored.

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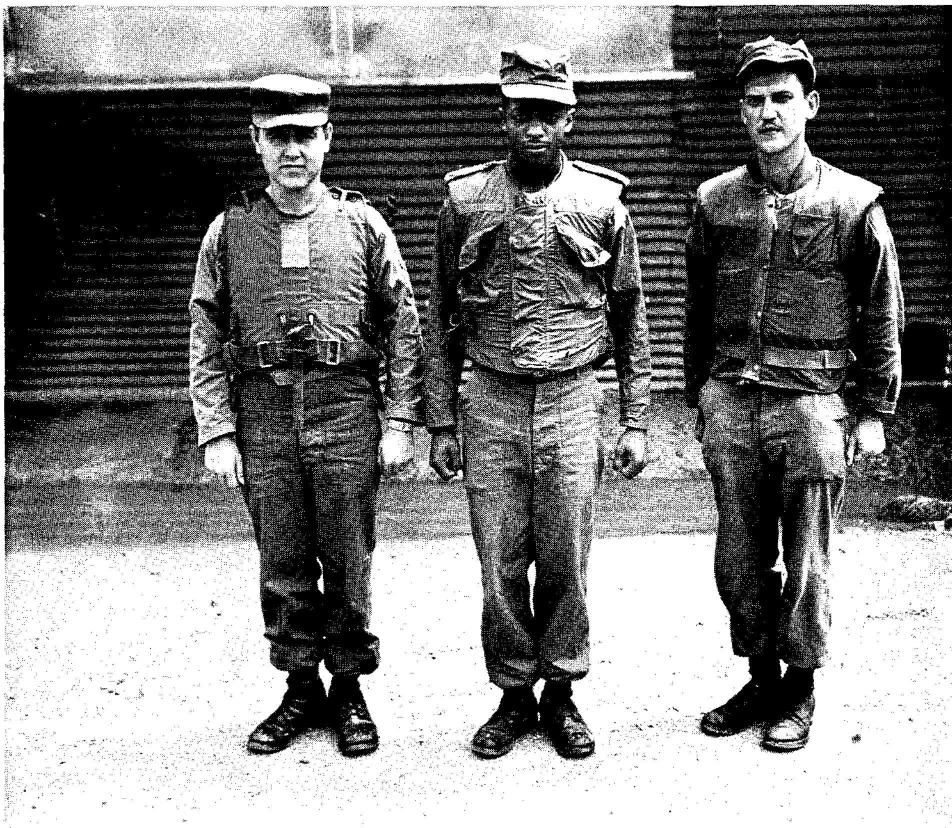


SC 436428

FIGURE 351.—Three members of the R & I Platoon, 443d QM Group modeling types of armored vest. (Left to right) World War II flyer's armor; Army all-nylon vest, T52–3; and Marine Corps doron-nylon vest. 14 August 1953.

e. That the tactical significance of body armor and methods for employing it be studied.

f. That load studies and climatic factors in relation to body armor be completely evaluated.

g. That consideration be given to the role of body armor in atomic warfare.

h. That the protective qualities of body armor against radiation and blast injury be studied.

i. That the protective qualities of body armor against incendiary weapons, especially white phosphorus, napalm, and flame throwers be evaluated.

j. That consideration be given to modifying the present prototype * * *.

There followed a list of specific changes which in general were intended to increase flexibility, improve fit and make the vest in general more comfortable. Others aimed at increasing the area of protection particularly under the arm,

SC 411153

FIGURE 352.—Men of Company L, 38th Infantry, 2d Division, rebuilding their stronghold near Old Baldy, 21 September 1952. Armor vests of the following types can be identified: (left to right) World War II M12, Marine Corps doron-nylon type, and Army T52–1 type.

and making easier removal from casualties. Only a few of them will be listed and illustrated.

3. Change the method of closure. Recommend an easily operated zipper with a protecting fly, provided with an alternate closing method (fig. 354).

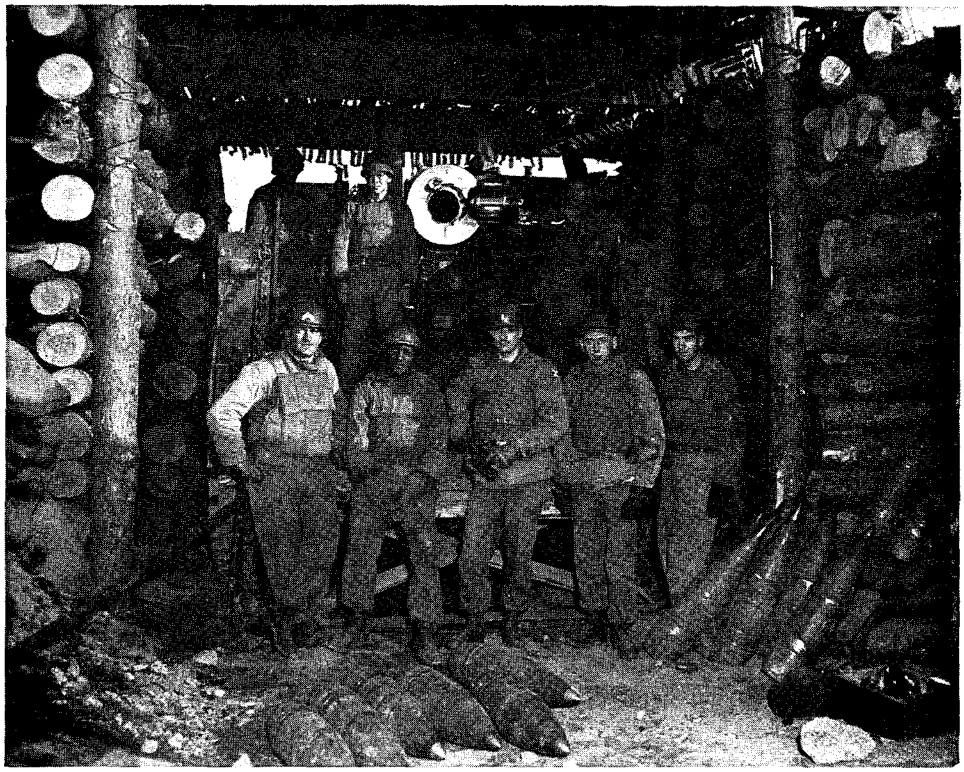
6. Replace the cover with a durable material which has more surface resistance to prevent slippage or carrying straps. The cover material should be non-reflecting (fig. 355), water resistant and of a color which blends with natural terrain features. It should not create sound when flexed or rubbed against other objects.

8. Replace the pockets with dash-type pockets * * *.

9. A means for carrying grenades be provided on the front of the vest * * *. A tape above the pockets into which the handle of the grenade could be inserted would satisfy this requirement.

10. Replace the present method of side fastening with one that is adjustable, elastic, and with a quick release mechanism which will permit easy removal from casualties.

11. Construct the vest so as to give maximum protection to the area under the arm (figs. 356 and 357).



SC 423912

FIGURE 353.—Crew of the self-propelled "killer" gun wearing World War II M12 body armor. Punchbowl Area, Korea, 3 July 1953.

12. Eliminate metal in the construction of the vest wherever possible to reduce secondary missile potential.
13. Eliminate the sponge rubber layer inside the nylon armor.

During the test period recommendations for modifications of the model T52–1 were solicited from the troops who had worn it in combat. These proposed changes were forwarded to the Research and Development Division of the Office of the Quartermaster General. Some of these tentative design modifications were incorporated into a new vest, model T52–2 (fig. 358). A total of 276 of the new models were received on 9 July 1952. Unfortunately, these were in use for only 6 days when the mission of the Body Armor Test Team was curtailed. A cursory survey revealed that the T52–2 was much more acceptable than its prototype.

Upon return of the body armor team in July 1952, three of its members, Colonel Cox, Major Irving, and Captain Daniels, with the assistance of Mr. William Persico, Clothing Development Branch, Philadelphia Quartermaster Depot, Pa., designed and fabricated a nylon body armor vest based upon the full, final recommendations of the team. This resulted in the armored vest,

T52-3 (fig. 359). Among other improvements, it included a new covering material, a two-piece sliding back, lace-type expandable side closure, combination metal zipper and snap front closure, and a more flexible type of spot welding of the layers of nylon cloth. This was the prototype which finally became the Army standard item of issue in the fall of 1952. The first shipment of the standard Army nylon vest left the Philadelphia Quartermaster Depot on or about 3 December 1952.

MEDICAL STUDY OF KIA CASUALTIES

At the same time that the body armor team was operating in Korea, concurrent studies at the Graves Registration Service Group, Kokura, Japan, on the killed in action casualties were being accomplished. These wound ballistics studies entailed a careful examination of each remains as to:

a. Exact anatomical location of all wounds (this to be demonstrated by both pictures and charts).

FIGURE 354.—Body armor. Front view of recommended design, showing front closure and grenade carrying loops.

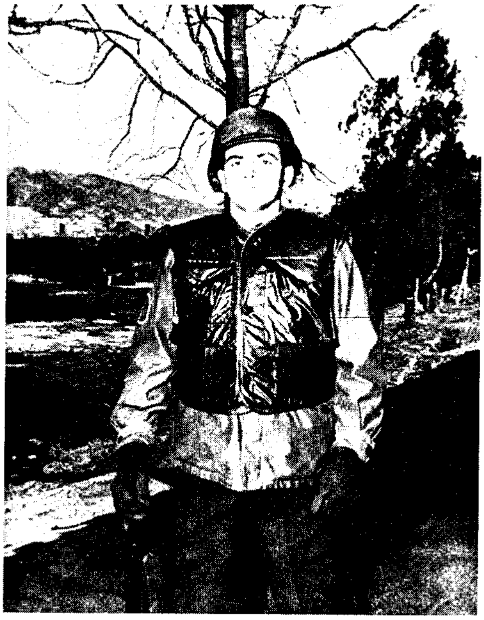


FIGURE 355.—Reflection of light from surface of body armor, T52–1.

FIGURE 356.—Unprotected area under arms in body armor, T52–1.

b. Type missiles causing wounds, i.e., shell fragments or small arms. (By the use of X-rays it was possible in most cases to determine the type missile, provided, of course, it remained within the body.)

c. Type wound or wounds, i.e., penetrating or perforating; penetrating meaning a wound having an entrance point but not an exit, perforating meaning a wound having both an entrance and an exit.

d. Tracing out the missile path and determining the cause of death.

e. Recovery of all wounding missiles when possible so that these may be photographed, weighed and identified.

f. Take sections of tissue for microscopic study.

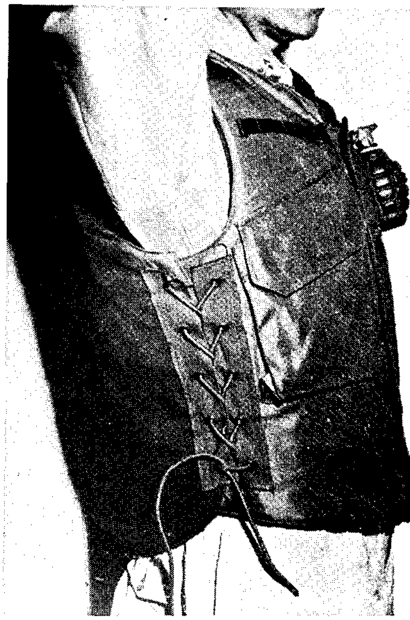
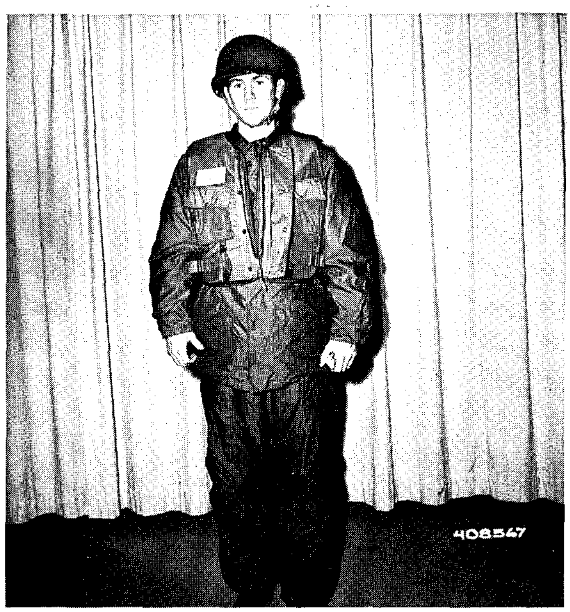
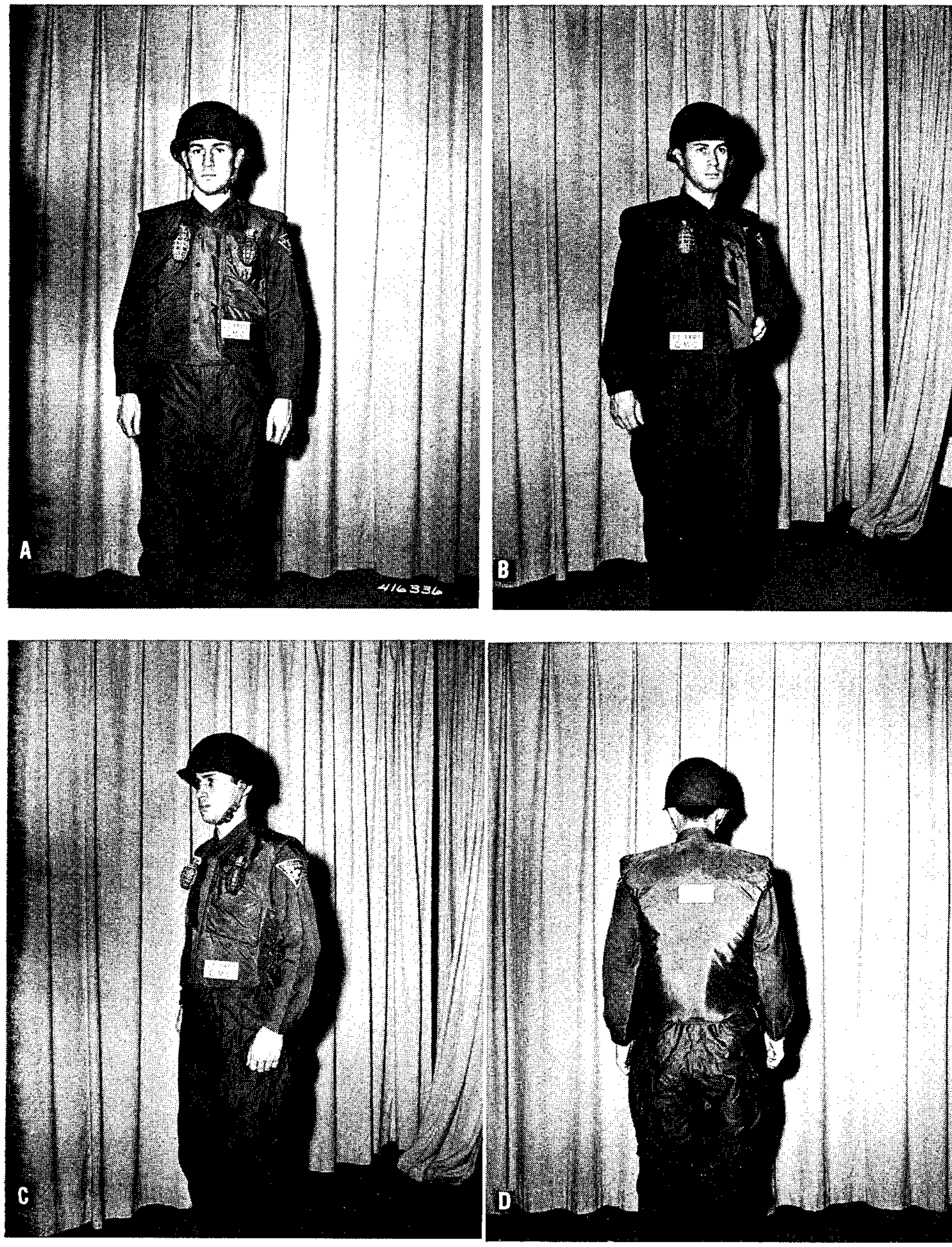


FIGURE 357.—Recommended protection and side closure, in body armor.



SC 408567

FIGURE 358.—Armor, vest, nylon, T52–2. This vest is made of 12 layers of spot-laminated nylon cloth. The covering of this model is double; an inner water-resistant vinyl film layer and an outer layer of 6-ounce nylon fabric. The new slash-type breast pockets and adjustable side straps also distinguish the revised model. Vest open, showing the zipper that has been introduced in this model and the fly which covers the same and is held in place by four snap fasteners. The same type of snap fasteners is used on the pockets. (Front view)



SC 416336, 416338, 416337, 416340

FIGURE 359.—Armor, vest, nylon, T52–3. Note new covering material, redesigned pockets, grenade and shoulder straps and side closure. (The trousers are not protective armor.) A. Front view. B. Front view showing closure. C. Side view. D. Rear view.

The initial survey of KIA casualties [10] was begun in March 1952 by Lieutenant Coe, who was joined in April 1952 by Major Enos. During the month of March 1952, the number of remains that were suitable for autopsying were relatively few. The majority of the bodies which arrived at Kokura were badly decomposed and offered little for a wound ballistic study. During the winter months, the method of using ships for transporting the bodies had been adequate, but with the coming of warmer weather this method was wholly unsatisfactory. On 6 April 1952, an air evacuation plan [11] was placed in effect. Specifically, this meant that the remains arrived in Kokura in approximately 24 to 36 hours after death on the frontlines in Korea. During part of this time, the bodies were kept in reefers (refrigerators) so that their condition upon arrival at Kokura was excellent.

KIA Casualty Survey, 20 March–1 July 1952

In the period from 20 March to 23 April 1952, 268 current deaths were processed through the American Graves Registration Service Group at Kokura. Of these cases, 173 with 618 wounds were examined for the area and regional frequency of wounds and also for the type of wounds. Because of the lack of time and the shortage of personnel, it was impossible to examine every case. Therefore, it was decided to examine in detail only cases in which death could be unquestionably attributed to enemy action and which presented reasonable promise of furnishing a rather complete picture. Autopsies were performed on 81 cases. Missiles were often hard to recover, but when found they were photographed, identified, and weighed. Most of the casualties during this period were incurred by personnel not wearing an armored vest when the lethal injury was sustained because the number of all types of armored vests available was small. Because of the small number of cases available, no attempt was made to draw conclusions.

During the remaining 15 months of the war, numerous wound ballistics teams from the Zone of Interior conducted surveys at the Graves Registration Service Group, Kokura, and made surveys of WIA casualties at the Tokyo Army Hospital. The work at Kokura was continued by Major Enos who, during the period from 24 April 1952 to 1 July 1952, examined 346 cases with a total of 1,346 wounds. Autopsies or wound track dissections were performed on all cases, and the information was forwarded to the Biophysics Division of the Chemical Corps Medical Laboratories for analysis. This revealed the regional distribution of wounds presented in table 299.

[10] (1) Coe, G. B.: Wound Ballistics, Killed in Action, Korea, 20 March 1952–23 April 1952. CmlC Medical Laboratories Research Report No. 116, June 1952. (2) Coe, G. B.: Wound Ballistics, Killed in Action, Korea, 24 April 1952–12 July 1952, vol. II. CmlC Medical Laboratories Research Report No. 144, October 1952. (3) Coe, G. B., Stoughton, R. B., and Debiec, R. P.: Wound Ballistics, Killed in Action, Korea, 12 November 1952–1 March 1953, vol. III. CmlC Medical Laboratories Research Report No. 221, October 1953.

[11] Cook, J. C.: Graves Registration in the Korean War. The Quartermaster Rev., pp. 18 and 131–144, March–April 1953.

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TABLE 299.—*Regional distribution of 1,346 wounds in 346 KIA casualties*

Region	Number of wounds	Percent of wounds
Thorax:		
Upper left side	149	11.1
Upper right side	101	7.5
Lower left side	78	5.8
Lower right side	65	4.8
Total	393	29.2
Head and neck	351	26.1
Extremities:		
Lower	325	24.1
Upper	207	15.4
Total	532	39.5
Abdomen	70	5.2
Grand total	1,346	100.0

The 346 cases showed 209 (60.4 percent) with single wounds and 132 cases (39.6 percent) having multiple wounds, or a ratio of 1.5 singly wounded to multiply wounded. Regional breakdown showed this ratio was 4.4 for the head and neck (140 cases), 1.7 for the thorax (137 cases), 1.2 for the abdomen (20 cases), and 1.5 and 1.4 for the upper (10 cases) and lower (39 cases) extremities, respectively. Fragmentation-type missiles accounted for about 66 percent of the wounds (table 300) and about 71 percent of the wounds were penetrating (table 301). Table 302 shows the regional distribution of 128 lethal wounds in 103 of the KIA casualties which were examined during this period. The partial selection of the casualty sample is apparent in the high number of lethal wounds of the thorax and in the low number of lethal wounds of the head.

Comparison of Army and Marine Corps Casualties

In the period between July to November 1952, another survey team (Colonel Holmes, Capt. James C. Beyer, MC, and Capt. Joseph V. Michalski, MSC) worked at Kokura. Approximately 3,000 current death cases were reviewed and information was obtained on wound distribution in 1,500 KIA casualties. This was a period of great flux in regard to body armor. The Marine Corps had standardized a combination doron-nylon vest. This consisted of 13 layers of nylon cloth over the upper part of the thorax and the shoulder girdle area and 20 overlapping doron plates over the remainder of the thorax and the upper part of the abdomen. This vest (M1951) (fig. 360) was standardized by 16 November 1951, and by 14 July 1952 approximately 9,772

TABLE 300.—*Distribution of 1,346 wounds in 346 KIA casualties, 24 April–1 July 1952, by causative agent*

Causative agent	Number of wounds	Percent of wounds
Fragments:		
Shell	485	36. 0
Mortar	246	18. 3
Artillery	68	5. 0
Landmine	44	3. 3
Grenade	39	2. 9
Total	882	65. 5
Small arms:		
Type unspecified	217	16. 1
"Burp" gun	144	10. 7
Rifle	22	1. 6
Pistol	14	1. 1
Total	397	29. 5
White phosphorus	2	. 2
Burns	65	4. 8
Total	67	5. 0
Grand total	1, 346	100. 0

TABLE 301.—*Distribution of 1,346 wounds in 346 KIA casualties, 24 April–1 July 1952, by type of wound*

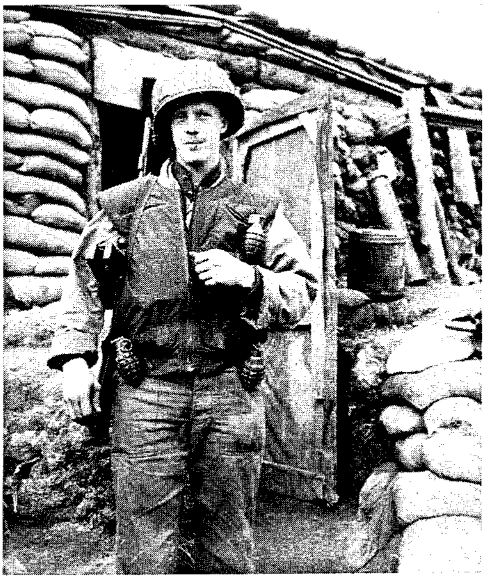
Type of wound	Number of wounds	Percent of wounds
Penetrating [1]	952	70. 7
Perforating [2]	244	18. 1
Avulsion [3]	133	9. 9
Decapitation	17	1. 3
Total	1, 346	100. 0

[1] Wounds of entrance but no exit; missile retained.
[2] Wounds of entrance and exit.
[3] Traumatic loss of large sections of a body area; amputations included.

vests were on hand in the 1st Marine Division in Korea. Therefore, all Marine Corps frontline personnel were probably equipped with body armor before this latter date. During this time, the Army was still conducting its field testing of all-nylon body armor. In order to provide their frontline troops

TABLE 302.—*Entrance location of 128 lethal wounds in 103 KIA casualties, 24 April–1 July 1952, by body region*

Body region	Number of lethal wounds	Percent of lethal wounds
Head	13	10.2
Neck	3	2.3
Thorax	77	60.2
Abdomen	22	17.2
Extremities:		
Upper	4	3.1
Lower	9	7.0
Total	128	100.0



SC 412792

FIGURE 360.—Pfc. David W. Jackson, Company L, 5th Regimental Combat Team, Eighth U.S. Army, wearing the Marine Corps doron-nylon vest, M1951, 27 September 1952.

with protection, 13,020 Marine vests (M1951) were requested on 11 August 1952 by the Army. The requests continued through March 1953 and by 19 September 1952 approximately 19,705 vests were supplied to the Army. This number was increased (approximately 63,000) until the Army vest was standardized and in production. The first shipment of this latter vest (T52–3) was released in the early part of December 1952 (see fig. 359). From December 1952 through September 1953, approximately 26,161 vests of this type were

shipped from continental United States. Before the availability of the Marine-type body armor, Army units were supplied with a limited number of M12 vests developed during World War II.

A comparison of Marine Corps KIA casualties from 1 July to 1 November 1952 and Army KIA casualties from 15 June to 1 September 1952 revealed the regional distribution of wounds shown in table 303. The Marine Corps personnel can be considered to be wearing body armor and the Army personnel were generally unarmored. There is a reduction of 9.6 percent in the total wounds of the thorax in the Marine Corps casualties and a 1.1 percent reduction in wounds of the abdomen as compared to the Army casualties.

TABLE 303.—*Regional distribution of 3,526 wounds in 354 Army* [1] *and 2,308 wounds in 355 Marine Corps personnel* [2] *killed in action*

Body region	Army personnel, without armor		Marine Corps personnel, with armor	
	Number	Percent	Number	Percent
Head	236	6. 7	198	8. 6
Face	202	5. 7	136	5. 9
Neck	191	5. 4	108	4. 7
Thorax	942	26. 7	390	16. 9
Abdomen	219	6. 2	118	5. 1
Extremities:				
Upper	663	18. 8	513	22. 1
Lower	1, 045	29. 7	836	36. 2
Genitalia	28	. 8	9	. 4
Total	3, 526	100. 0	2, 308	100. 0

[1] Surveyed from 15 June to 1 September 1952.
[2] Surveyed from 1 July to 1 November 1952.

The Marine Corps casualties included 355 cases with a total of 2,308 wounds for a 6.5 wound incidence per casualty. Among the wounds, 80.9 percent were penetrating in type, 14.9 percent were perforating, and 4.2 percent were amputations. According to the causative agent, 85.4 percent were produced by fragmentation-type weapons, 12.8 percent by small arms, and 1.8 percent were unknown.

The Army casualties included 354 cases with a total of 3,526 wounds for a 9.9 wound incidence per casualty. According to wound type, 87.9 percent were penetrating; 9.1 percent, perforating; and 3.0 percent, amputations. Fragments were responsible for 86.2 percent of the wounds, small arms for 11.7 percent, and 2.1 percent were unidentified.

Table 304 lists the regional distribution of lethal wounds in the two casualty samples. The armored Marine Corps casualties show a 12.1 percent reduction in lethal wounds of the thorax and a 1.1 percent reduction in lethal wounds of the abdomen as compared to the Army personnel.

TABLE 304.—*Regional distribution of lethal wounds in 354 Army*[1] *and 355 Marine Corps*[2] *personnel killed in action*

Region wounded	Army personnel, without armor		Marine Corps personnel, with armor	
	Number	Percent	Number	Percent
Head	155	31.6	178	32.1
Face	30	6.1	52	9.4
Neck	28	5.7	47	8.5
Thorax	177	36.1	133	24.0
Abdomen	46	9.4	43	7.8
Extremities:				
Upper	10	2.0	26	4.7
Lower	44	9.1	75	13.5
Total	490	100.0	554	100.0

[1] Surveyed from 15 June to 1 September 1952.
[2] Surveyed from 1 July to 1 November 1952.

Tables 305 and 306 summarize the types and numbers of body armor vests available to the Eighth U.S. Army, 31 December 1952–29 February 1953.

TABLE 305.—*Status of armor vests, available to major Army units,*[1] *31 December 1952*

Unit	Type of body armor vest			
	Marine[2]	Army nylon[3]	M12[4]	Total
	Number	*Number*	*Number*	*Number*
2d Division	4,062	600	1,017	5,679
3d Division	4,064	948	269	5,281
7th Division	4,604	460	938	6,002
25th Division	4,600	1,063	492	6,115
40th Division	4,064	598	1,111	5,773
45th Division	4,064	598	315	4,977
5th RCT	1,454	91		1,545
Army troops	560	226	644	1,430
Reserve and maintenance	504		6,081	6,585
1st BCW Division	1,558			1,558
Total	29,534	4,584	10,867	44,985

[1] Data derived from Staff Report, Quartermaster Section, Headquarters, Eighth U.S. Army, November and December 1952.
[2] Constructed of doron plates and nylon cloth.
[3] T52-1 and -2 all-nylon body armor. This was the type used during the Army body armor test period.
[4] Army World War II body armor; aluminum plates with nylon cloth.

TABLE 306.—*Status of armor vests, available to major Army units,*[1] *29 February 1953*[2]

Unit	Type of body armor vest available		
	M12 and Marine standard issue	Standard Army issue	Total
	Number	*Number*	*Number*
2d Division	7, 500	3, 523	11, 023
3d Division	6, 100	3, 508	9, 608
7th Division	5, 500	3, 514	9, 014
25th Division	6, 800	4, 914	11, 714
40th Division	6, 100	3, 663	9, 763
45th Division	6, 500	3, 646	10, 146
5th RCT	3, 470		3, 470
1st BCW Division	1, 900		1, 900
United Nations units	2, 755		2, 755
Total	46, 625	22, 768	69, 393

[1] Data derived from Staff Report, Quartermaster Section, Headquarters, Eighth U.S. Army, February 1953.
[2] In January and February 1953, armored vests were issued to bring each division up to or over its authorized level of 8,390 vests. Approximately 8,400 excess M12 vests were turned over to the Republic of Korea Army.

After body armor had become widely used, information was desired on the effect of the body armor vests on the regional frequency of lethal wounds. A survey of killed in action was accomplished at Kokura during the period of November 1952 to March 1953 by Lieutenant Coe and 1st Lt. Richard B. Stoughton.[12] During the period of this survey, there were approximately 60,000 vests in use by U.S. Army divisions on the frontlines in Korea. Therefore, only those cases wearing body armor at the time they received the lethal wound or wounds were used in this survey. It was necessary for members of the team to travel to every unit on the frontlines of Korea and talk with personnel in the casualty's squad, platoon, or company to determine accurately if body armor had been worn at the time the lethal wound was inflicted. From approximately 600 cases investigated, 500 definitely were wearing armor at time of death. Only these cases were used. These data were then compared with previous surveys conducted between April and July 1952 during which time armor was not widely used. The general tactical situation had remained appreciably the same over the whole period of these surveys. Action consisted largely of aggressive patrolling with stable main lines of resistance. Enemy use of artillery had increased, but there were no massive withdrawals or offensives by friendly forces during the time between the compared surveys. Table 307 shows the comparison of lethal wounds in the two casualty samples.

[12] See footnote 10 (3), p. 753.

TABLE 307.—*Entrance location of lethal wounds in 206* [1] *casualties not wearing armor and in 500* [2] *wearing armor*

Entrance location	Without armor		With armor		Percent change
	Number	Percent	Number	Percent	
Head	25	12. 1	207	41. 4	+29. 3
Neck	11	5. 4	72	14. 4	+9. 0
Thorax	119	57. 8	110	22. 0	[3] −35. 8
Abdomen	28	13. 6	41	8. 2	−5. 4
Extremities:					
Upper	5	2. 4	13	2. 6	+. 2
Lower	18	8. 7	57	11. 4	+2. 7
Total	206	100. 0	500	100. 0	

1 Survey 20 March to 1 July 1952; 154 KIA casualties with 206 lethal wounds.

2 Survey 15 November 1952 to 1 March 1953; 500 KIA casualties with 500 lethal wounds.

3 The value of body armor for the thorax appears higher than in other comparable surveys due to the fact that a selection of cases was made in the first survey period. Initially, the main interest was in wounds of the thorax and abdomen only and a considerable number of cases with wounds in other body regions, for example, head, were excluded. Later, all types of cases were studied, but the early selection is still reflected in the overall figures.—J. C. B.

There was an apparent reduction of approximately 36 percent [13] in lethal thoracic wounds in the group wearing the armored vest. The nylon vest also covered part of the upper part of the abdomen, especially the liver and the kidneys. This may account for the 5.4 percent reduction in lethal abdominal wounds among those wearing the armored vest.

Among the 500 KIA casualties wearing body armor, there were 3,510 total wounds recorded. The types of wounds were distributed as follows: 3,068 wounds (87.4 percent) penetrating, 198 wounds (5.7 percent) perforating, 170 avulsions (4.8 percent), 50 lacerations (1.4 percent) (superficial but extensive wound), and 24 (0.7 percent) decapitations. With this same casualty sample, the causative agent for the wound was recovered in 437 instances. A fragment was identified in 293 (67.1 percent) of the cases and small arms in 110 (25.1 percent) of the cases. Table 308 lists the regional distribution of the 3,510 wounds in the 500 casualties. Multiple wounds were present in 364 (72.8 percent) of the cases and 136 (27.2 percent) had only a single wound.

The importance of multiple wounding in casualty production cannot be overemphasized. In the survey on casualties wearing body armor, there was an average of seven wounds per case. This figure is below the actual number since it was almost impossible to count every wound on some of the cases. Compared with this, for WIA casualties, the average is about two wounds. In any one region an additional wound, aside from the lethal wound, might conceivably increase the chances of death by additive or even synergistic effects. Also, it is quite possible that one missile entering a body cavity, such as the thorax, would not strike a vital area, but additional missiles entering the cavity

13 Other surveys would indicate a reduction of only approximately 12 percent.—J. C. B.

TABLE 308.—*Regional distribution of 3,510 wounds in 500 KIA casualties wearing body armor, November 1952–March 1953*

Region	Number of wounds	Percent of wounds
Head	473	13. 5
Neck	160	4. 5
Thorax	553	15. 7
Abdomen	260	7. 4
Extremities:		
Upper	700	20. 0
Lower	1, 364	38. 9
Total	3, 510	100. 0

would increase the chances of the heart or great vessels being hit. Another possibility is that KIA casualties are slower to be evacuated than the wounded from the battlefield. They are thus exposed to enemy fire longer and might sustain additional hits after receiving a lethal wound. Whatever the reason or combinations of reasons, reduction of the number of wounds is extremely desirable.

Collection of Battle Casualty Data

In the early days of the Korean War, medical records of battlefield wounding were too inexact in their nomenclature to permit exhaustive wound ballistic studies. In 1951, an effort was made to correct this. Medical personnel were requested to record the exact type of wounding missile on the EMT (emergency medical tag). For example, instead of recording "shell fragment" or "shrapnel," they were asked to identify the missile as being artillery, mortar, hand grenades, landmine, and so forth. It was also found that the casualty was frequently able to identify the exact nature of the missile causing his wound. By making the effort to get this information on the spot, when events were fresh and the information most readily available, the data would then appear on all the patient's medical records and be readily accessible for compiling into wound ballistics data. The results of this effort were reflected in the more exact nature of the weapon frequency charts compiled later in the war. In the first casualty survey, approximately 85 percent of the total number of wounding missiles were listed by the ambiguous term "shell fragments." In the last survey conducted in the Korean War, only 39.6 percent of the wounds were identified as being due to "shell fragments."

In 1952, medical officers and battalion aid station personnel were asked to note on the record accompanying each KIA casualty whether he had been wearing an armored vest and helmet at time of wounding. This request met with considerable success in the latter stages of the war, but with constant

changes in personnel many cases came through without a notation concerning the wearing of a vest or a helmet.

Indoctrination of medical personnel on the importance of accurately recording wound ballistics data on the EMT could best be accomplished at the Medical Field Service School. A recommendation was made by all wound ballistic teams operating in Korea that the present EMT be modified by the adding of "body armor worn or not worn," "helmet worn or not worn," and "type missile causing wound." This would be of paramount importance in future wars for the successful operation of all wound ballistic teams. In addition, a simple but comprehensive method for locating wounds, for example, an anatomic chart with body regions demarcated, would be of great value. Figure 361 illustrates the demarcation of body regions [14] which is advocated

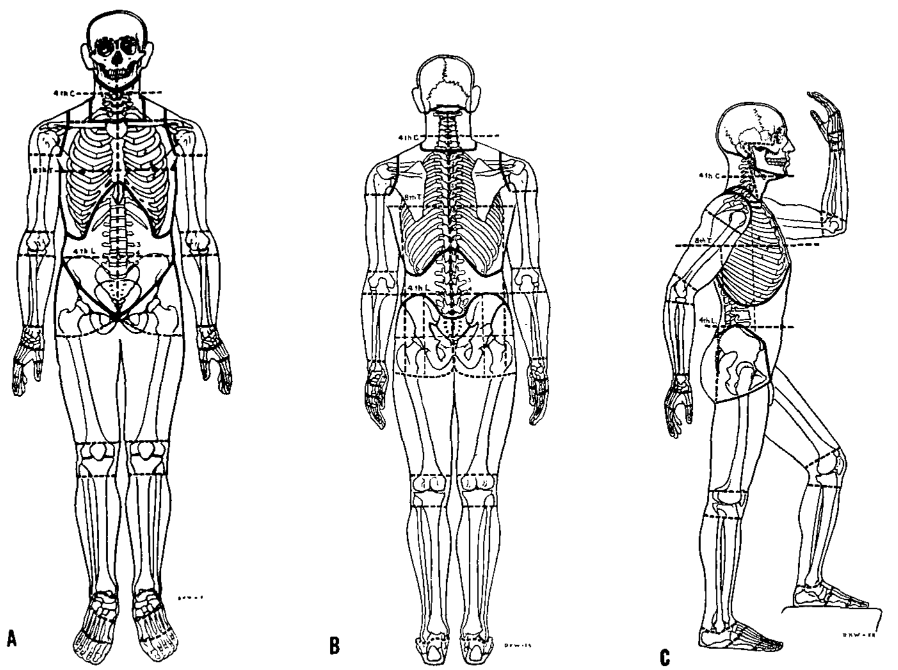


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FIGURE 361.—Demarcation of anatomic surface regions. Skeletal views. A. Anterior view. B. Posterior view. C. Lateral view.

for use by battle casualty survey units. This was the regional demarcation used by the survey team at Kokura from July to November 1952 and also by Major Enos and Captain Beyer in the KIA survey from May to August 1953.

[14] Holmes, R. H., Enos, W. F., and Beyer, J. C.: Demarcation of Body Regions. U.S. Armed Forces M. J. 5:1610–1618, November 1954.

Helmet Survey

During the period from 9 January to 1 March 1953, a study on the battlefield performance of the M1 steel helmet was conducted in Korea by Lieutenant Coe.[15] The study was made by collecting all available helmets hit on the battlefield by enemy fire. The helmets were then forwarded through Graves Registration channels to the Central Identification Unit, Kokura, with information on (1) the type of missile that hit the helmet (grenade, mortar, "burp" gun, and so forth), (2) a complete description of what happened to the individual wearing the helmet, (3) the type of wounds sustained, and (4) the exact location of the wounds. After proper coordination with the Medical and Quartermaster Sections, an order implementing this was published by the Adjutant General, Headquarters, Eighth U.S. Army, Korea, and sent to all division surgeons for their information and coordination with their battalion aid station personnel.

A total of 45 helmets were received during this period of time. It had been hoped that many more helmets would be recovered and forwarded with the information requested. Personal contact with battalion aid station surgeons at a later date revealed the numerous difficulties involved in recovering the helmets. Soldiers who had sustained hits on their helmets without receiving a wound did not want to give up their helmets and in many instances did not turn them in. There was also added danger in attempting recovery of damaged helmets from exposure to enemy fire during the time required for recovery.

The 45 helmets examined sustained a total of 71 hits. A breakdown on these is as follows:

	Number
Missile perforated steel shell and liner	60
Missile perforated steel shell but not liner	3
Missile was completely defeated by helmet	7
Missile perforated liner only	1
Total	71

Although 85 percent of the hits did go completely through both helmet and liner, not all of these resulted in death or even in a serious wound. In some instances, the steel shell and liner were perforated with the individual not sustaining a wound. The wounds sustained in these cases revealed the following:

	Number
Wounded through helmet	16
Helmet hit, no wounds	7
Helmet hit, wounded elsewhere	2
Killed through helmet	16
Helmet hit, killed by wound elsewhere	4
Total	45

[15] Coe, G. B.: Battlefield Performance of the M-1 Steel Helmet. CmlC Medical Laboratories Research Report No. 248, February 1954.

Thus, 16 of 45 cases were killed as a result of helmet defeat by the missile. In 13 of 45 cases the missile was defeated successfully, although some of these cases resulted in death from wounds elsewhere on the body. Many of the 16 nonlethal wounds sustained through the helmet were potentially lethal. (This was judged from the direction the missile was traveling.) Therefore, in assessing the effectiveness of helmet protection, these reductions in wound severity must be considered. From the tabulation just presented, it can be seen that in over half the cases studied, possible death resulting from head wounds was prevented by the helmet.

Analysis of the types of missiles involved in the 71 hits showed the following:

	Number
Mortar	32
Artillery	16
Small arms	10
Shell fragment, type unknown	9
Landmine	1
Hand grenade	1
Secondary missile	1
Unknown	1

Not all soldiers wore their helmet, because of its weight, lack of stability, and so forth. Many men on patrols complained about the noise made by the helmet when it came in contact with bushes and twigs and felt also that the helmet interfered with their hearing. For these reasons, some men on patrol preferred not to wear their helmets. These objections to the helmet can be overcome by continuing indoctrination and by improving the helmet characteristics, especially its stability on the head.

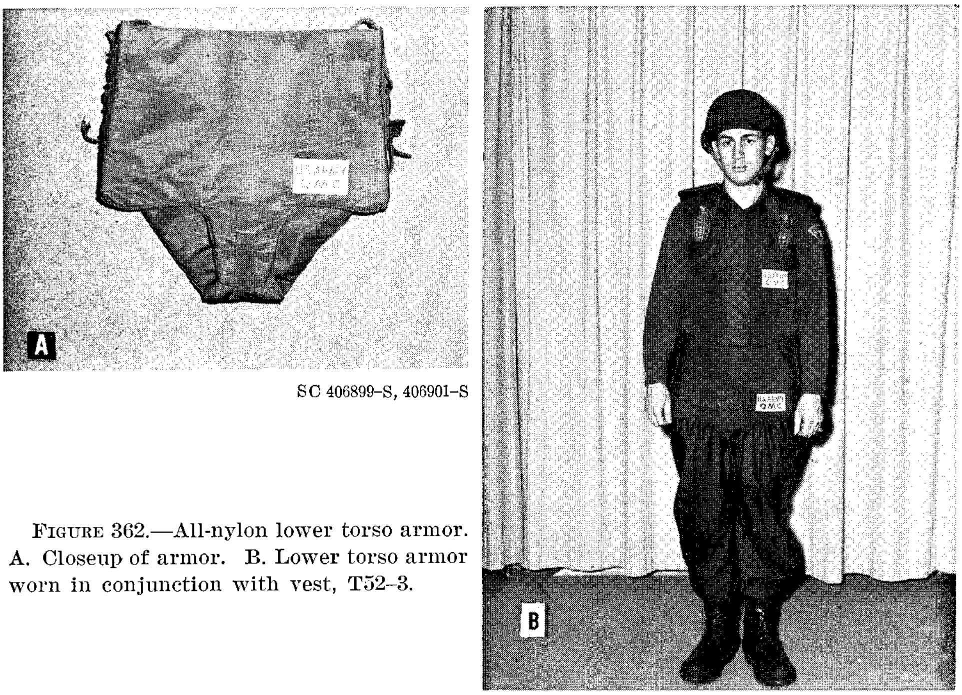
Information was received on two cases in which soldiers had to seek cover hurriedly from incoming mortar fire. In both cases, the helmet came off when the soldier hit the ground. Both men were then killed by head wounds, from fragments of the next incoming round. It cannot be said that these men would have been saved had their helmets not come off; however, from the 45 cases studied, it can be seen that they would have had an increased chance of survival had their helmets stayed on.

LOWER TORSO ARMOR

In addition to the development of the all-nylon body armor vest, a lower torso armor was also fabricated (fig. 362). The new armor was designed to be worn with the Army's armored vest and, like the vest, was made of 12 layers of flexible, spot-laminated nylon duck inclosed within a water-resistant vinyl layer with an outer covering of 6 ounce nylon fabric. The lower torso armor provided for the hips, abdomen, and groin the same degree of protection the armored vest gave the upper torso, and there was some degree of overlapping between the two garments. The new lower torso armor resembled boxer's shorts and was supported by suspenders worn under the armored vest.

IMPROVISED ARMOR FOR SPECIAL PURPOSES

In addition to these experimental and standard items of issue, a considerable number of armored "suits" were devised by the personnel in Korea in an attempt to provide protection to individuals engaged in minefield clearance. Some of these models were produced from the ballistic materials in the World War II M12 vest and portions of the World War II flyer's armor (fig. 363). Others were developed from either the Army or Marine Corps upper torso armor in conjunction with overlapping plates of doron applied to the abdomen and upper and lower extremities (fig. 364).



SC 406899–S, 406901–S

FIGURE 362.—All-nylon lower torso armor. A. Closeup of armor. B. Lower torso armor worn in conjunction with vest, T52–3.

It is difficult to summarize quantitatively the effects of body armor in the Korean War; however, certain tentative conclusions are permitted by the battlefield studies and by the impressions gained by the team members.

1. There was a decrease in the number of personnel killed in action.
2. There was a decrease in the number of personnel wounded in action.
3. There was a decrease in the severity of wounds in those areas protected by the vest.
4. There was a decrease in the convalescence time of many of the wounded in action.
5. There was a decrease in the workload of medical personnel.
6. There was an increase in the percentage of wounded in action who returned to frontline duty.

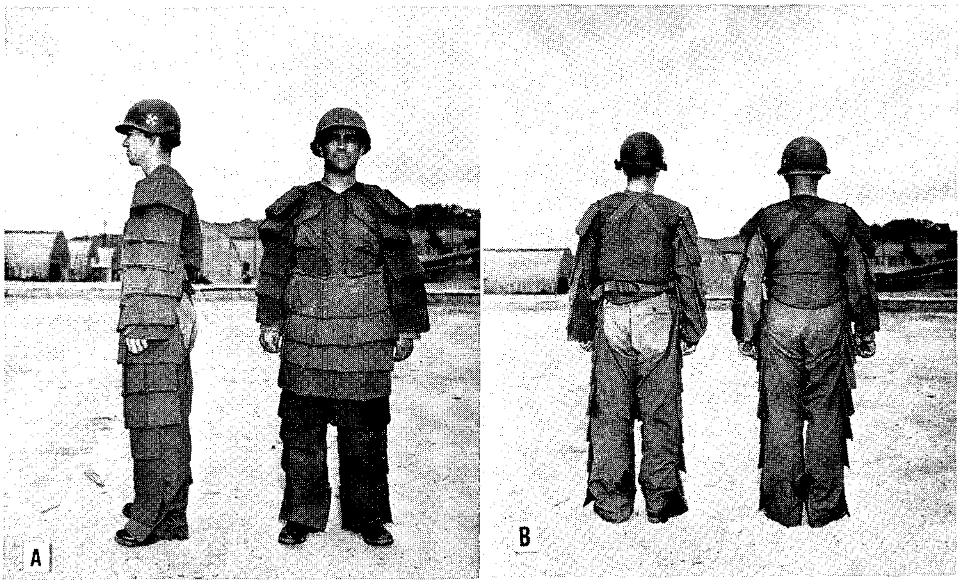
U.S. Army photo

FIGURE 363.—Armored suit for use by mine clearance personnel, World War II M12 vest components and World War II flyer's apron, 15 March 1952.

7. There was an increase in the confidence and fighting spirit of the majority of troops wearing body armor.

Many of the medical officers in Korea felt that the armored vest was one of the most effective forms of preventive medicine introduced in the Korean War. It may safely be concluded that use of body armor coupled with rapid helicopter evacuation of casualties to mobile army surgical hospitals improved medical and surgical care, and extensive use of whole blood was responsible for the saving of many lives in Korea.

The advantages gained through the wound ballistics studies and body armor test teams during the Korean War can only be perpetuated by an active and purposeful continuation of certain activities during peacetime and immediate, full reactivation of all units in the event of hostilities. A medical program for the study of wounds and wounding is presented in appendix I, page 851.



SC 461059, 461060

FIGURE 364.—Armored suit for use in demolition work, 3 August 1953. A. Front view, overlapping doron plates. B. Rear view, Marine Corps vest (left) and Army vest, T52–3.

APPENDIX A

Casualties, 1st Battalion, 148th Infantry, 37th Division New Georgia Campaign, 18 July–5 August 1943

James E. T. Hopkins, M.D.

In the following pages, the various engagements of the 1st Battalion, 148th Infantry, are grouped into tactical situations, and casualties are described in the order in which they occurred in combat.

Tactical Situation No. 1, 18 July 1943

The 2d Battalion of the 148th Infantry landed at Zanana Beach on 18 July and, with a few men from the 1st Battalion, moved 1 mile up the Munda trail and dug in for the night. During the day, a patrol from Company G had located a Japanese machinegun emplacement covering the trail about 300 yards from the Barike River. In spite of this knowledge, the regimental S–3 (operations and training) advanced along the trail with several vehicles, and the following casualty occurred:

Case 1.—Severe penetrating wounds of the entire body. This man was a truck driver in the forward vehicle advancing on the enemy-held Munda trail. He was struck by .25 caliber light machinegun fire at a 60-yard range. Classified as KIA, died instantly. This type of patrol was unnecessary; the patrol leaders had been warned about the machinegun.

Tactical Situation No. 2, Night of 18 July 1943

The 1st Battalion set up a perimeter for the night along the Munda trail, a half mile from the beach, deep in the jungle. Two casualties were sustained that night.

Case 2.—Severe penetrating wound of the lower third of the left leg. This man stood up from his foxhole in the early morning hours of 19 July and was shot by another soldier with a .30 caliber rifle at a range of approximately 10 to 20 yards. Classified as WIA, second echelon type. This casualty occurred during the first night that the men were in combat; they had not had previous contact with the enemy.

Case 3.—Severe perforating wound of the head. This man sat up in his foxhole while talking in his sleep during the early morning hours of 19 July and was shot by another soldier with an M1 rifle at a range of approximately 20 to 30 yards. Classified as KIA. This casualty occurred under circumstances similar to those of Case 2.

Tactical Situation No. 3, 19–20 July 1943

At 1100 hours on 19 July, while the 2d Battalion, 148th Infantry, was held in reserve, the 1st Battalion advanced west along the Munda trail to the first branch of the Barike River, with Company A leading the column. The advance was frequently slowed by fire from enemy snipers.

At 1200 hours, when the medical aidmen were resting at the rear of the column, word reached them that a litter squad was required. The circumstances were found to be as follows:

The jungle along this section had been thinned by artillery fire during a previous engagement. The trail on the far side of a small jeep bridge which spanned the Barike River was

moderately flat, and the jungle was thinned out for an area of about an acre. On the right, on the U.S. Army side of the bridge, a steep hill fell to the water in front and to the road on the side. On the left of the route, the jungle was flat, but very dense. Several dugouts were located on each side of the stream. As Company A crossed the bridge, two heavy enemy machineguns started firing; and, during the course of action for the next 24 hours, 5 men were killed and 11 wounded. The Japanese sustained at least 25 casualties, half definitely killed by rifle and automatic weapons fire and the remainder by mortar and artillery fire.

Case 4.—Multiple, severe penetrating wounds of the upper and lower extremities and of the scrotum. This man, a member of a patrol moving in single file, was struck by the first burst from a Japanese heavy machinegun. He was wounded at 1100 hours on 19 July but managed to pull himself into a dugout where he remained for 30 hours during which time he managed to kill three Japanese. He was evacuated on 20 July and was classified as WIA, U.S. evacuation type.

Case 5.—Multiple, severe penetrating and perforating wounds of the lower extremities. This man was wounded while walking single file on an open trail, and 6 hours after his initial wound he received additional fatal grenade and bayonet wounds. Classified as KIA.

Case 6.—Severe perforating wound of the thorax. This man was a member of a patrol walking single file in an open trail when he was struck by fire from a Japanese heavy machinegun at a range of approximately 100 yards. Classified as KIA.

Case 7.—Severe perforating wound of the thorax. This man was killed under circumstances similar to those of Case 6. Classified as KIA.

Case 8.—Moderately severe laceration of the head. This man was on patrol when he was struck by Japanese machinegun fire at a range of approximately 100 yards. He received a dressing for his wound and was evacuated 20 hours later. Classified as WIA, first echelon type.

Case 9.—Moderately severe penetrating wound of the right arm. This man was struck by heavy machinegun fire at a range of approximately 100 yards. He received a dressing for his wound and was evacuated 20 hours later. Classified as WIA, second echelon type.

Case 10.—Moderately severe penetrating wound of the left arm. This man was wounded by Japanese machinegun fire. After receiving an initial dressing for the wound, he was evacuated some 20 hours later. Classified as WIA, second echelon type.

Case 11.—Moderately severe penetrating wound of the left leg. This man was wounded by Japanese machinegun fire. After an initial dressing, he was evacuated some 20 hours later. Classified as WIA, second echelon type.

Case 12.—Multiple penetrating wounds of the face. This man, while on patrol, was injured by Japanese heavy machinegun fire. He was evacuated immediately. Classified as WIA, U.S. evacuation type.

Case 13.—Penetrating wounds of the foot with fractures of the metatarsal bones. This man was wounded while on patrol. He was evacuated immediately. Classified as WIA, U.S. evacuation type.

Case 14.—Severe penetrating wound of the left leg. This man was wounded while on patrol. Classified as WIA, second echelon type.

Case 15.—Moderately severe laceration of the left arm. This man was a member of a patrol. He managed to escape the initial burst from a Japanese heavy machinegun but was wounded several minutes later while attempting to roll out of the lane of fire. He was wounded at a range of approximately 100 yards. Classified as WIA, immediate duty type.

Case 16.—Multiple penetrating and perforating wounds of the thorax and the abdomen. This medical aidman was killed while attempting to reach a casualty. He was struck by fire from several heavy machineguns at a range of approximately 100 yards. This man was advancing in a standing crouch position and should have been crawling. Classified as KIA.

Case 17.—Multiple, severe penetrating and perforating wounds of both lower extremities. This aidman was advancing in a standing crouch position in an attempt to reach a casualty. His lower extremities were splinted, and he was evacuated within 1 hour. Am-

putation of the right lower extremity was performed several days later. Classified as WIA, U.S. evacuation type.

Case 18.—Moderately severe penetrating wounds of the right arm. This man, a member of a patrol, was struck by the initial burst of Japanese heavy machinegun fire. Classified as WIA, first echelon type.

Case 19.—Severe perforating wound of the head. This man, while on defensive action, was crawling into a dugout with two other soldiers when a bullet from a Japanese heavy machinegun passed through the slits between the logs of the dugout and produced a fatal wound. Classified as KIA.

On 20 July, the following two casualties occurred:

Case 20.—Severe perforating wound of the lower part of the right leg. This man, while walking about the perimeter shortly after leaving his foxhole, was struck by a .25 caliber bullet. He received 1 unit of plasma and was evacuated 2 hours later. Classified as WIA, U.S. evacuation type.

Case 21.—Severe perforating wounds of the right leg. This man, while on offensive action walking to one side of the trail, was struck by a .25 caliber bullet. Classified as WIA, second echelon type.

During tactical situation No. 3, the American forces consisted of approximately two platoons of infantry plus heavy weapons, and the Japanese forces consisted of not more than one platoon with heavy and light machineguns. The 1st Battalion forces sustained a total of 21 casualties, 7 KIA and 14 WIA. The Japanese forces sustained about 25 to 50 casualties, 18 of whom were estimated as being due to small arms fire and the remainder as being due to mortar and heavy artillery fire.

Tactical Situation No. 4, 21 July–1 August 1943

On 21 July 1943, the 1st Battalion advanced against little enemy resistance to a parachute drop at which the 169th Infantry had been relieved the previous day by the 2d Battalion. The 2d Battalion had reached the area by bypassing the Japanese resistance. A raiding party of 100 to 200 Japanese had attacked a litter party of the 118th Medical Battalion, Collecting Company B, and approximately 40 men were buried in this area; 10 were casualties and 8 were litter bearers.

Most of the activities during the next 3 days consisted of patrol duty. The 1st Battalion had four casualties from U.S. artillery fire and six from enemy automatic weapons fire. On the morning of 25 July, three casualties resulted from friendly artillery fire.

In the late afternoon of 25 July, the 1st Battalion dug in on the right side of O'Brien Hill. A small patrol was dispatched on what was called a "suicide mission" in an attempt to obtain prisoners. Although the enemy was said to be poorly armed, the patrol met heavy resistance from automatic weapons fire and three were wounded. The objective of the patrol was not accomplished.

On 26 July, two casualties were sustained from grenade fragments.

During the late afternoon of 27 July, the 1st and 2d Battalions dug in 300 yards west and to the right of O'Brien Hill, at what was to be a supply dump. Very little enemy activity took place during the day. On the same day, however, a group of engineers had attempted to build a jeep trail to the area of the supply dump, and, after they had been ambushed by Japanese snipers, two men were killed and several others wounded.

At 0700 hours on 28 July, the regimental commander requested that the 1st Battalion send out two litter squads with a protecting rifle squad to pick up the bodies of the two engineers just mentioned. Although no enemy resistance had been anticipated, heavy small arms fire was encountered; five men were killed and one was wounded. The bodies of the two engineers were not recovered.

Although at least a company of Japanese troops were known to be on the left flank, the 1st and 2d Battalions were ordered to advance approximately 700 yards on a 270° azimuth.

Company A, with an unprotected mortar squad, was left to guard the ration dump. When this company sent out a platoon in an attempt to bring back a casualty and clean up enemy resistance, the platoon was obliged to retreat back to the ration dump without accomplishing either mission.

In the meantime, the 1st and 2d Battalions successfully advanced to their destination overlooking Munda airfield, sustaining only one casualty. When a bulldozer trail from the ration dump followed the advancing battalions, 2 men were killed in action during the late afternoon of 28 July and 11 were wounded in action.

On the morning of 29 July, it was learned that the ration dump was surrounded by the enemy and that the trail was not open. All remaining wounded were therefore evacuated by jeeps over the enemy-held trails.

The two battalions advanced toward the ration dump during the day of 29 July. The 1st Battalion, which was in the rear position, sustained only one casualty. On the morning of 30 July, the 2d Battalion walked single file around the enemy resistance and retreated from the area. The 1st Battalion did not disperse the enemy or open the trail to the ration dump until 1200 hours on 1 August 1943. Between 30 July and 1 August, it had 92 casualties, 17 of whom were KIA or DOW. No evacuation was available for the wounded from 1600 hours on 28 July until 1200 hours on 1 August.

An interesting sidelight of this particular engagement is that, between 30 July and 1 August, the 160th Infantry was unable to make full use of its supporting artillery during its attack on the three hills which lay across their line of advance because the location of the 1st Battalion was so uncertain the free use of the artillery would probably have caused many casualties among U.S. troops.

During the tactical situation described between 21 July and 1 August 1943, U.S. forces engaged varied in strength, at any single time, from one platoon to a maximum of 1,000 infantry troops. The opposing Japanese strength was estimated at 200 to 500 troops. The 1st and 2d Battalions, 148th Infantry, sustained 219 casualties, of whom 53 were KIA.

A discussion of the 1st Battalion casualties (112) and a description of the circumstances under which they occurred during the 21 July–1 August action follow.

On 21 July 1943, the 1st Battalion took over part of the 169th Infantry area and the following casualties occurred:

Case 22.—Minor laceration of the right side of the thorax. This man was on defensive action walking over irregular, thick jungle terrain when he was struck by a .25 caliber rifle bullet at a range of approximately 100 or 200 yards. Classified as WIA, immediate duty type.

Case 23.—Minor penetrating wound of the left side of the thorax. This man, while in a foxhole during an American artillery barrage, was struck by a shell fragment at a range of approximately 100 yards. Classified as WIA, immediate duty type.

Case 24.—Moderately severe laceration of the lower part of the right thigh directly over the patella. This man, in a position similar to that of Case 23, was wounded by American artillery fire. Classified as WIA, first echelon type.

Case 25.—Moderately severe laceration of the left arm. This man, in a position similar to that of Case 23, was struck by American artillery fire. Classified as WIA, second echelon type.

Case 26.—Moderately severe penetrating wounds of the head. This man, in a position similar to that of Case 23, was struck by American artillery fire. Classified as WIA, first echelon type.

Case 27.—No record available.

The following casualties occurred when a small party protecting a bulldozer ran into an ambush:

Case 28.—Severe penetrating wound of the thorax. This man, while walking on patrol, was struck by a burst of .25 caliber machinegun fire at an unknown range. Classified as KIA.

Case 29.—Multiple, severe penetrating wounds of the left upper and lower extremities. This man was on patrol when he was struck by a burst of a .25 caliber machinegun fired at an unknown range. Classified as WIA, second echelon type.

Case 30.—Penetrating wounds of the left upper extremity. This man was on patrol when he was struck by bullets from a .25 caliber sniper's rifle at an unknown range. Classified as WIA, first echelon type.

Case 31.—Multiple, moderately severe penetrating wounds of the face and head. This man, while on patrol, was in a kneeling position firing his rifle when it was struck by a .25 caliber rifle bullet. Numerous small metal fragments penetrated his face and forehead. Classified as WIA, immediate duty type.

On 25 July, the following casualties resulted from a U.S. artillery barrage:

Case 32.—Severe penetrating wound of the head. This man was in a foxhole when an American artillery shell burst directly overhead. A fragment of the shell passed through his helmet. Classified as KIA, died 10 minutes after injury.

Case 33.—Moderately severe lacerating wound of the left shoulder region. This man was wounded under circumstances similar to those of Case 32. Classified as WIA, first echelon type.

Case 34.—Moderately severe penetrating wound of the right foot. This man was wounded under circumstances similar to those of Case 32. Classified as WIA, second echelon type.

Cases 35 and 36.—Both these casualties sustained moderately severe penetrating wounds of the thorax and the legs. These men were wounded under circumstances similar to those of Case 32. Classified as WIA, second echelon type.

On 26 July, a small combat patrol was sent to take prisoners from an isolated enemy dugout. If the activity of the patrol had been properly planned, all of the following casualties might have been avoided:

Case 37.—Multiple small arms wounds of the thorax and abdomen. This man, while on patrol, was just climbing over a log in thick jungle when he was struck by a burst of .25 caliber light machinegun fire at a range of approximately 25 to 50 yards. Classified as KIA.

Case 38.—Severe penetrating wound of the head. This man, while on patrol, was standing behind the tree attempting to point out the enemy when he was struck by a burst of .25 caliber machinegun fire. Classified as KIA.

Case 39.—Severe penetrating wounds of the head. This man was in a prone position attempting to throw a grenade when he was struck by fragments from a Japanese grenade and by machinegun fire. The range was approximately 35 yards. Classified as WIA, U.S. evacuation type.

Case 40.—Multiple, severe penetrating wounds of the lower part of the abdomen and the lower extremities. This man was a member of an advancing patrol when he was struck by fragments from a Japanese grenade. After sustaining his injuries, the soldier walked 200 yards to the regimental aid station where he received primary treatment. He was evacuated immediately but died 28 hours later without having received any surgical treatment. He received 1 unit of plasma. This man was classified as DOW, 28 hours' survival.

Case 41.—Moderately severe lacerating wound of the right leg. This man was on patrol when he was struck by fragments of a Japanese hand grenade. Classified as WIA, first echelon type.

Case 42.—Moderately severe penetrating wound of the left thigh. This man was on patrol when he was struck by fragments of a Japanese hand grenade. Classified as WIA, second echelon type.

On 28 July, the following casualties occurred:

Case 43.—Mild penetrating wounds of the left leg. This man was in a shallow foxhole when he was struck by fragments from an American artillery shell which burst at a 75- to 100-yard range. Classified as WIA, immediate duty type.

Case 44.—Mild lacerating wound of the left arm. This man was wounded under circumstances similar to those of Case 43.

Case 45.—Severe penetrating wound of the right side of the face. This man was wounded under circumstances similar to those of Case 43. Classified as WIA, U.S. evacuation type.

Cases 46 through 49.—All these soldiers sustained multiple penetrating and perforating wounds due to .25 caliber light machinegun fire. Three of the men were killed instantly and the fourth was bayoneted to death several hours after receiving his primary wound. The machinegun range was from 50 to 100 yards. All of these men had been sent out to recover the bodies of two dead engineers. This entire action had been poorly planned and ill-advised.

Case 50.—Moderately severe laceration of the nose. This man was wounded under circumstances similar to those of Cases 46 through 49. Classified as WIA, U.S. evacuation type.

Case 51.—Severe perforating wound of the head. This man was killed under circumstances similar to those of Cases 46 through 49. Classified as KIA.

Case 52.—Severe mutilating wound of the right arm and moderately severe penetrating wounds of the thorax. This man was on offensive action, walking single file down an open trail, when a U.S. hand grenade exploded accidentally in front of him. Classified as DOW, lived 7 hours after injury. This casualty was due to careless handling of the grenade and, probably, to poor medical treatment.

Case 53.—Severe mutilation of the head and face. This man was on offensive action crawling toward an enemy machinegun emplacement when he was struck by a burst of .25 caliber machinegun fire at a 20-yard range. Classified as KIA. The platoon to which this soldier belonged had become disorganized, and this man did not receive any support in his attack on the enemy emplacement.

Cases 54, 55, and 56.—All of these men received multiple, minor penetrating wounds of the head and the extremities. These men were in a prone position in a foxhole when three enemy hand grenades were thrown into the foxhole. Two of the grenades were thrown out but the third exploded and wounded the men. All of these men were members of a mortar section that was not receiving adequate protection from a rifle squad, and their foxhole was poorly located. Classified as WIA.

Case 57.—No record of this casualty, very minor wound.

Case 58.—Moderately severe penetrating wound to the right forearm. This man was in a position similar to that of Case 54 and was wounded by enemy grenade fragments. Classified as WIA, second echelon type.

Case 59.—Severe perforating wound of the head. This man, in an unprotected foxhole with three other members of a mortar crew, was struck by a .25 caliber rifle bullet at a 25- to 50-yard range. Classified as KIA.

Case 60.—Severe perforating wound of the head. This man was killed under circumstances similar to those of Case 59.

Case 61.—Severe perforating wound of the right leg. This man was walking about the perimeter organizing the defense when he was struck by a burst of .25 caliber light machinegun fire. He was wounded at 1700 hours on 28 July but was not evacuated until 0700 hours on 29 July. Classified as WIA, U.S. evacuation type.

Case 62.—Moderately severe penetrating wound of the left leg. This man was on defensive action when he was struck by a bullet from a .25 caliber Japanese rifle. Classified as WIA, second echelon type.

Case 63.—Moderately severe laceration of the head. This man was struck by a Japanese rifle bullet. The bullet perforated his helmet. Classified as WIA, immediate duty type.

Case 64.—Penetrating wound of the head. This man was in a foxhole when he was struck by a Japanese rifle bullet. Classified as WIA, second echelon type.

Case 65.—Multiple penetrating and perforating wounds of the right upper extremity and a penetrating wound of the head. This man was in a foxhole when he was struck by a burst of enemy light machinegun fire. Classified as WIA, U.S. evacuation type, and was returned to duty in 8 months.

On 29 July the 1st Battalion sustained the following casualty:

Case 66.—Severe perforating wound of the right hand. This man was in a foxhole when he accidentally discharged his own rifle. He was wounded at 1800 hours on 29 July and was evacuated at 1200 hours on 1 August. Classified as WIA, U.S. evacuation type. This casualty could have been avoided.

On 30 July heavy casualties were sustained:

Case 67.—Moderately severe penetrating wound of the left leg. This man, while on an offensive action, was advancing in a crouch position when he was struck by a Japanese rifle bullet at a range of approximately 50 to 100 yards. He was wounded at 1400 hours on 30 July and was evacuated at 1200 hours on 1 August. Classified as WIA, second echelon type.

Case 68.—Severe perforating wound of the thorax. This man was wounded under circumstances similar to those of Case 67. Following his injury, the soldier walked 100 yards to the aid station. Classified as WIA, second echelon type.

Case 69.—Moderately severe penetrating wound of the left shoulder. This man was wounded under circumstances similar to those of Case 67. Classified as WIA, second echelon type.

Case 70.—Severe penetrating wound of the left hand. This man was wounded under circumstances similar to those of Case 67. Classified as WIA, second echelon type.

Case 71.—Severe penetrating wound of the left forearm and the left leg. This man was on offensive action in a crawling position when he was struck by fragments from a Japanese hand grenade at a 1-yard range. Classified as WIA, U.S. evacuation type.

Case 72.—Severe penetrating wound of the left thigh. This man was on offensive action in a crawling position when he was struck by enemy light machinegun fire at a 50- to 75-yard range. Classified as WIA, second echelon type.

Case 73.—Moderately severe penetrating wound of the head and face. This man was in a foxhole on defensive action during a Japanese counterattack when he was struck by fire from an enemy light machinegun. One bullet perforated his helmet. After being wounded, he was able to walk back to the aid station. Classified as WIA, first echelon type.

Case 74.—Moderately severe penetrating wound of the left leg. This man was wounded by fire from an enemy light machinegun. Classified as WIA, U.S. evacuation type.

Case 75.—Severe penetrating wound of the head. This man was crawling toward an enemy machinegun emplacement and continued to advance alone even after orders had been given for a withdrawal. He was struck by fire from the machinegun at a 25-yard range. Classified as KIA. Deafness probably was responsible for the death of this casualty.

Case 76.—Severe perforating wound of the head. This man was standing in a foxhole telephoning when he was struck by a rifle bullet at a 75- to 100-yard range. Classified as KIA. This casualty could have been avoided.

Case 77.—Multiple, severe perforating and penetrating wounds of the thorax and the upper and lower extremities. This man had just left his foxhole located on the defensive perimeter in attempt to contact the division when he was struck by a burst of enemy light machinegun fire. Classified as WIA, U.S. evacuation type.

Case 78.—Moderately severe penetrating wound of the left foot. This man was struck by an enemy rifle bullet at a range of approximately 50 yards. Classified as WIA, second echelon type.

Cases 79 and 80.—Minor wounds, no records available.

Case 81.—Mild penetrating wound of the left thigh. This man was in a crawling position when he was struck by an enemy rifle bullet at a range of approximately 50 yards. Classified as WIA, immediate duty type.

Case 82.—Severe penetrating wound of the left thigh. This man was in a foxhole when he was struck by an enemy rifle bullet at a 75-yard range. Classified as WIA, second echelon type.

Case 83.—Minor, severe penetrating wound of the right leg. This man was on offensive action advancing against the enemy when he was struck by an enemy rifle bullet at a range of approximately 75 yards. Classified as WIA, second echelon type.

Case **84.**—Multiple penetrating wounds of the face. This man was on offensive action standing in moderately thick jungle when he was struck by fragments from an enemy knee mortar shell. Classified as WIA, second echelon type.

Case 85.—Moderately severe penetrating wounds of the right leg. This man was wounded under circumstances similar to those of Case 84. Classified as WIA, second echelon type.

Case 86.—Severe perforating wound of the abdomen. This man was on offensive action advancing in a crouched position through moderately thick jungle terrain when he was struck by a machinegun bullet at a range of approximately 75 yards. Classified as DOW, died 30 minutes after being hit.

Case 87.—Multiple, moderately severe penetrating wounds of the right lower extremity. This man was on offensive action crawling through thick jungle terrain when he was struck by fragments from an enemy hand grenade thrown from a tree. The grenade detonated a few feet away from the casualty. Classified as WIA, first echelon type.

Case 88.—Multiple, moderately severe penetrating wounds of the left upper and lower extremities. This man was wounded under circumstances similar to those of Case 87. Classified as WIA, first echelon type.

Case 89.—Severe penetrating wound of the right shoulder region. This man was advancing in a standing position in moderately thick jungle terrain when he was struck by an enemy rifle bullet at a range of approximately 75 yards. Classified as WIA, second echelon type.

Case 90.—Perforating wound of the right foot. This man was on offensive action advancing through moderately thick jungle when he was struck by an enemy rifle bullet at a 75-yard range. Classified as WIA, first echelon type.

Case 91.—Moderately severe lacerating wound of the left leg. This man was struck by an enemy rifle bullet at a 75-yard range. Classified as WIA, second echelon type.

Case 92.—Multiple, severe perforating wounds of the abdomen. This man was on offensive action advancing in a crouched position through moderately thick jungle when he was struck by a burst from an enemy light machinegun at a 50- to 100-yard range. Classified as DOW, lived 1 hour after injury.

Case 93.—Multiple, severe perforating wounds of the thorax. This man was wounded under circumstances similar to those of Case 92. Classified as KIA.

Case 94.—Severe perforating wound of the thorax. This man, standing in a foxhole telephoning, was warned to take cover when he was struck by an enemy rifle bullet at a range of approximately 100 to 200 yards. Classified as KIA. This casualty could have been avoided.

Case 95.—Severe perforating wound of the thorax. This man was struck by fragments from an enemy mortar shell at an unknown range. Classified as WIA, U.S. evacuation type.

Case 96.—Severe perforating wound of the abdomen and multiple, mild penetrating wounds of the right thigh. This man was walking in the perimeter to deliver a message when he was struck by fragments of the same mortar shell which struck Case 95. Classified as DOW, died 9 days after injury.

Case 97.—Severe mutilation of the head. This man had been assisting in the digging of a hole for a machinegun emplacement when he left the protection of the hole and moved

a few feet away. He was struck by a burst from an enemy light machinegun at a range of approximately 50 to 100 yards. Classified as KIA. This man should not have left the protection of his foxhole.

Case 98.—Perforating wound of the neck. This man was standing in a foxhole in proximity to the aid station when he was struck by an enemy rifle bullet at a 75-yard range. Classified as WIA, second echelon type. This area had been under fire from enemy snipers, and this man should not have been standing in an exposed position.

Case 99.—Multiple penetrating wounds of the face and of the upper extremities. This man was firing his rifle when it was struck by an enemy rifle bullet. Numerous small metal fragments penetrated his face and arms. Classified as WIA, second echelon type.

Case 100.—Moderately severe penetrating wound of the posterior portion of the right thigh. This man was entering a foxhole when he accidentally sat on the tip of a bayonet. Classified as WIA, first echelon type.

On 31 July the following casualties occurred:

Case 101.—Minor wound, no record available.

Case 102.—Severe perforating wound of the abdomen. This man was in a foxhole on defensive action when he got up to obtain ammunition. He was struck by enemy light machinegun fire at a 50- to 100-yard range. Classified as DOW, died 2 days after injury.

Case 103.—Severe penetrating wound of the abdomen and moderately severe penetrating wound of the left shoulder. This man had already prepared one foxhole when he was told to dig a new one. It was obvious he was to dig this new hole in a lane of enemy fire, and he attempted to avoid this new order. Shortly after, he was struck in the shoulder by an enemy light machinegun bullet and, as he was being moved to the aidman's hole, he received the abdominal wound. This man received no treatment other than morphine and died after 2 hours in the aidman's foxhole. Classified as DOW, with a 2-hour survival. This casualty probably could have been avoided.

Case 104.—Severe penetrating wound of the left side of the thorax. This man was digging a foxhole when he was struck by an enemy light machinegun bullet at the same time as Case 103. He was treated by the aidman but died 2 hours later. Classified as DOW, with a 2-hour survival time.

Case 105.—Severe penetrating wound of the abdomen. This man was returning from patrol and was approaching the aidman's foxhole when he was struck by an enemy light machinegun bullet. He received treatment from the aidman but died in 1 hour. Classified as DOW, with a 1-hour survival.

Case 106.—Moderately severe penetrating wounds of the right leg. This man was on offensive action advancing toward the Japanese line in a crouched position when he was struck by an enemy light machinegun bullet at a 15-yard range. After this man received his wound, he became confused and crawled toward the enemy line. He was pulled into a Japanese foxhole, and when his body was recovered it was found that he had been strangled to death by a rope. Classified as KIA.

Case 107.—Multiple, superficial penetrating wounds of the face. This man was advancing toward the enemy lines when he was struck by numerous fragments from a Japanese hand grenade. Classified as WIA, first echelon type.

Case 108.—Moderately severe penetrating wound of the right arm. This man was advancing toward the enemy line when he was struck by an enemy rifle bullet. Classified as WIA, first echelon type.

Case 109.—Moderately severe penetrating wound of the neck. This man was in a foxhole furnishing machinegun fire for the advancing troops when he was struck by a Japanese rifle bullet. Classified as WIA, first echelon type.

Cases 110 and 111.—Minor wounds, no records available.

Case 112.—Severe penetrating wound of the left shoulder. This man was struck by fragments of an enemy hand grenade at an unknown range. Classified as WIA, first echelon type.

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Case 113.—Severe penetrating wound of the right hand. This man was advancing toward the enemy line when he accidentally fell and discharged his M1 rifle. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 114.—Severe perforating wound of the right thigh and laceration of the left buttock. This man was on defensive action and left his foxhole to procure rations when he was struck by an enemy machinegun bullet at a 100- to 150-yard range. Classified as WIA, second echelon type.

Case 115.—Minor laceration of the head. This man was in his foxhole on defensive action when a Japanese rifle bullet passed through his helmet and lacerated his scalp. Classified as WIA, second echelon type.

On 1 August 1943, all Japanese resistance described in tactical situation No. 3 (p. 769) ended at 1200 hours. During the later stages of this engagement, Company A, 1st Battalion, was very successful and was able to knock out a light machinegun and several heavy U.S. machineguns which the Japanese had taken from the 169th Infantry. The Japanese, who were dressed in U.S. uniforms and helmets, also used other U.S. equipment.

Fifteen enemy dead were found in the area, and considerable numbers of Japanese were known to have escaped into the jungle. The 1st Battalion sustained 18 casualties, as follows:

Case 116.—Moderately severe perforating wound of the thorax. This man was on offensive action and was advancing with his machinegun crew when a Japanese light machinegun opened fire. While attempting to take cover in a shellhole, the soldier was struck by an enemy light machinegun bullet as he was assuming the prone position. Classified as WIA, second echelon type.

Case 117.—Moderately severe penetrating wound of the left forearm. This man was wounded under circumstances similar to those of Case 116. Classified as WIA, second echelon type.

Case 118.—Severe penetrating wound of the head. This man was advancing against the enemy lines and was wounded under circumstances similar to those of Case 116. Classified as WIA, second echelon type.

Case 119.—Severe mutilation of the head. This man was on offensive action and was taking cover behind a tree when he was struck by a burst from an enemy light machinegun. Classified as KIA.

Case 120.—Moderately severe penetrating wound of the neck. This man was struck by an enemy rifle bullet at a 50- to 100-yard range. Classified as WIA, immediate duty type.

Case 121.—Minor laceration of the thorax. This man was on offensive action when an enemy machinegun bullet ricocheted off his helmet. After taking cover, he was wounded by a fragment from an enemy hand grenade. Classified as WIA, immediate duty type.

Case 122.—Severe penetrating wound of the head. This man was struck by an enemy light machinegun bullet. Classified as KIA, death occurred in 10 minutes.

Case 123.—Mild laceration of the thorax. This man was struck by a fragment from an enemy hand grenade at an unknown range. Classified as WIA, first echelon type.

Case 124.—Severe perforating wound of the right foot. This man, while in a prone position, was attempting to kick away an enemy hand grenade which had fallen near him. Classified as WIA, U.S. evacuation type.

Cases 125 and 126.—Minor wounds, no records available.

Case 127.—Moderately severe penetrating wound of the left buttock. This man was near the frontline of the perimeter when he was struck by fragments from an enemy hand grenade at an unknown range. Classified as WIA, first echelon type.

Case 128.—Moderately severe laceration of the face. This man, a member of a mortar crew, was struck by an enemy rifle bullet at a range of 150 yards. Classified as WIA, immediate duty type.

Case 129.—Moderately severe penetrating wound of the right leg. This man was on defensive action and accidentally stabbed himself with his own bayonet. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 161.—Moderately severe penetrating wound of the right thigh. This man was in a standing position on offensive action when he was struck by an enemy light machinegun bullet. Classified as WIA, first echelon type.

Case 162.—Minor laceration of the right leg. This man was struck by a U.S. rifle bullet. Classified as WIA, immediate duty type.

Case 163.—Severe penetrating wound of the head. This man was on offensive action when he stopped to pick up a cigarette butt. He was struck by an enemy light machinegun bullet. Classified as KIA. This casualty could have been avoided.

Case 164.—Severe penetrating wound of the thorax. This man was advancing against enemy lines when two American mortar shells fell short of the skirmish line. The first shell was a dud and did not explode, but the second shell exploded within several yards from this casualty. Classified as KIA. This casualty was due to carelessness on the part of the adjacent companies which did not maintain contact with each other.

Case 165.—Moderately severe penetrating wound of the left foot. This man was on offensive action advancing in a crouched position when he was struck by a Japanese light machinegun bullet at a 20- to 50-yard range. Classified as WIA, first echelon type.

Case 166.—Severe perforating wound of the thorax. This man was advancing in a standing position against the Japanese pillbox when he was struck by a light machinegun bullet. Classified as KIA.

Case 167.—Severe perforating wound of the thorax. This man was wounded under circumstances similar to those of Case 166. Classified as KIA.

Case 168.—Severe perforating wound of the thorax. This man was wounded under circumstances similar to those of Case 166. Classified as KIA, died within 10 minutes.

Case 169.—Minor wounds, no records available.

Case 170.—Multiple, severe perforating wounds of the left thigh. This man was digging a shallow foxhole in the company area when an enemy mortar shell burst at a 3-yard range. Classified as WIA, U.S. evacuation type.

Case 171.—Moderately severe penetrating wound of the right buttock. This man was digging a foxhole with Case 170 and was wounded by a fragment from an enemy mortar shell. Classified as WIA, first echelon type.

Case 172.—Moderately severe penetrating wound of the left shoulder area. This man was in a standing position digging a foxhole when he was wounded by a fragment from an enemy mortar shell. Classified as WIA, first echelon type.

Case 173.—Multiple, severe penetrating wounds of the head, neck, and shoulder. This man was sleeping in a very shallow foxhole when an enemy mortar shell struck 3 feet from his head. Classified as KIA.

Case 174.—Multiple penetrating wounds of the abdomen and the left lower extremity. This man was in the same foxhole with Case 173 and was wounded by fragments from a Japanese mortar shell. Since it was very dark and rainy, this man was not located for 10 minutes, and his abdominal wounds received initial treatment before it was found that he was bleeding from a lacerated femoral artery. He died from hemorrhage in about 15 minutes. Classified as KIA.

Case 175.—Multiple penetrating wound of the thorax and the upper and lower extremities. This man was sleeping in a foxhole adjacent to Cases 173 and 174 and was wounded by fragments from the same enemy mortar shell, which burst at a 1-yard range. Classified as WIA, first echelon type.

Cases 176 through 181.—All these men were in shallow foxholes at a 2- to 10-yard distance from the enemy mortar shellburst which caused casualties 173, 174, and 175. All classified as WIA, immediate duty type.

APPENDIX B

Casualties, 1st Battalion, 5307th Composite Unit (Provisional), Burma Campaign, 15 February–8 June 1944

James E. T. Hopkins, M.D.

In the following pages, the various engagements of the 1st Battalion, 5307th Composite Unit (Provisional), during the Burma campaign are grouped into tactical situations, and casualties are described in the order in which they occurred in combat.

A comparison of casualties sustained by the 1st Battalion during the period of actual combat from 5 March through 8 June 1944 with the number of enemy casualties is practically impossible because of lack of knowledge of either the Japanese forces or the casualties they sustained. The 1st Battalion sustained a total of 61 casualties, of whom 7 were killed in action. Of the 54 who survived the initial wounding, 8 died later of their wounds.

1.—While they were guarding the airstrip at Lagang Ga, near Walawbum, soon after entering Burma, elements of the 1st Battalion came under barrages from Japanese 77 mm. artillery at a range of 2½ miles. The first shells caught the troops without protection of foxholes, and eight casualties were sustained, as follows:

Case 1.—Multiple penetrating and mutilating wounds of the face and neck. This man was in a prone position on flat terrain in tall grass and bushes when an enemy artillery shell burst at a 1-yard range. Classified as DOW, with a 1-hour survival time. This casualty might have been avoided if the troops had taken advantage of protective cover and foxholes.

Case 2.—Multiple penetrating wounds of the thorax. This man was in a prone position when he was struck by fragments from an enemy artillery shell which had a tree burst at 25 yards. Classified as WIA, first echelon type.

Case 3.—Mild penetrating wounds of the left leg. This man was wounded under circumstances similar to those of Case 2. Classified as WIA, immediate duty type.

Case 4.—Multiple, severe penetrating wounds of the left thigh and face. This man was in a prone position when he was struck by fragments of an enemy artillery shell when it detonated at a 2-yard range. Classified as WIA, first echelon type.

Case 5.—Mild penetrating wound of the thorax. This man was in a prone position on the ground when he was struck by fragments of an enemy artillery shell which had a tree burst at 15 yards from his position. Classified as WIA, immediate duty type.

Case 6.—Moderately severe penetrating wound of the thorax and mild penetrating wound of the left leg. This man was wounded by fragments from an enemy artillery shell which detonated 10 yards from his position. Classified as WIA, first echelon type.

Case 7.—Mild laceration of the right hand. This man, while walking on patrol, was ambushed by a Japanese trail block and was struck by an enemy rifle bullet at a 15-yard range. Classified as WIA, immediate duty type.

Case 8.—Severe perforating wounds of the left upper and lower extremities. This man was riding horseback on patrol when the trigger of a Thompson submachinegun was caught in a twig and the weapon discharged. Classified as WIA, second echelon type. This casualty could have been avoided.

2.—After Walawbum, the 1st Battalion was assigned the task of throwing a roadblock below Shaduzup. A regiment of Chinese with pack artillery was attached to the battalion for the mission. En route to Shaduzup, the 1st Battalion encountered two enemy road-

blocks at Tabayin and Naprawa, and seven U.S. casualties were sustained while reducing enemy resistance as follows:

Case 9.—Severe penetrating wound of the head. This man, while on offensive action walking along a trail, was struck by a fragment from a Japanese knee mortar shell at a 3-yard range. Classified as WIA, U.S. evacuation type. This casualty might have been avoided if he had worn his helmet and taken advantage of protective cover.

Case 10.—Multiple, mild penetrating wounds of the neck and thorax. This man, while on patrol, was standing in the middle of a trail when he was struck by fragments from a Japanese knee mortar shell. Classified as WIA, first echelon type.

Case 11.—Moderately severe penetrating wound of the left arm. This man was walking along the side of the trail in rather thick jungle growth when he was struck by an enemy rifle bullet. Classified as WIA, first echelon type.

Case 12.—Multiple, severe penetrating wounds of the head. This man was walking in a crouched position along the side of the trail when he was struck by enemy light machinegun fire at a 25-yard range. Classified as KIA.

Case 13.—Severe perforating wound of the head. This man was in a prone position when he was struck by an enemy sniper's bullet at a 100-yard range. Classified as KIA.

Case 14.—Moderately severe perforating wounds of the left leg. This man was advancing in a crouched position along the side of a trail when he was struck by fire from an enemy light machinegun. Classified as WIA, second echelon type.

Case 15.—Multiple, severe penetrating wounds of the left lower extremity. This man was wounded under circumstances similar to those of Case 14. Classified as WIA, second echelon type.

3.—The 1st Battalion engaged the enemy at a strongly defended area at Htingdankawing and sustained the following casualties:

Case 16.—Severe perforating wound of the right leg. This man was in a prone position behind a clump of bamboo but for some reason was told to leave this position and retreat to the rear. While running down the center of the trail, he was struck by an enemy machinegun bullet at a 35-yard range. The wound track involved the right popliteal fossa with laceration of the popliteal artery. This wound was not dressed for 15 minutes following the injury, and the patient became hysterical and kicked the tourniquet off. The patient bled to death within a half hour. Classified as DOW, with a 30-minute survival time. This casualty might have been avoided if he had used better judgment about running down the trail and if he had been cooperative with the aidmen in their attempts at treatment.

Case 17.—Mild penetrating wound of the abdomen. This man was struck by fragments from a U.S. 60 mm. mortar shell which exploded at an unknown distance. Classified as WIA, immediate duty type. This casualty might have been avoided if the 60 mm. mortars had been properly located closer to the frontline.

Case 18.—Mild penetrating wound of the face. This man, while attempting to treat Case 16, was struck by a fragment from the same shell which wounded Case 17. Classified as WIA, immediate duty type.

Case 19.—Multiple penetrating wounds of the thorax and the left upper and lower extremities. This man was in a standing position when he was struck by fragments from an 81 mm. mortar shell at a 15-yard range. Classified as WIA, immediate duty type. This casualty might have been avoided if he had taken advantage of a prone position in protective cover.

Case 20.—Mild penetrating wound of the left upper extremities; no other record available.

Case 21.—Mild penetrating wound of the right thigh. This man was in a prone position in the midst of a bamboo clump when he was struck by fragments of a Japanese hand grenade which exploded within 5 feet of his position. Classified as WIA, immediate duty type.

4.—The 1st Battalion, with an attached Chinese regiment, had been advancing on Shaduzup over very difficult terrain and through virgin jungle for 2 weeks. They had fought several skirmishes with a few casualties.

On 27 March, the Americans, with the Chinese 24 hours behind, bivouaced with great care and secrecy on the east bank of the Nam Kawng Chaung, 3 miles below Shaduzup. The Chinese in the distance attracted attention with their campfires, and they were shelled by enemy 77 mm. guns. When the Chinese sent back several counterartillery barrages, they gave away their positions to the enemy and sustained numerous casualties. Shells began to fall in one of the 1st Battalion platoon areas, but they moved out, sustaining one casualty.

Case 22.—Severe penetrating wounds of the right temporal region of the head. This man was in a platoon area that was being shelled by the enemy and the platoon was being moved to a safer location. The man was not wearing a helmet, and in spite of orders to the contrary he returned to the original area to retrieve his pack. While walking around in the dark, he was struck by a fragment of an enemy 77 mm. artillery shell. It was 3 hours before the man was located, and it was 48 hours before he was treated by Seagrave Unit No. 2. Classified as DOW, with a 4-day survival period. This casualty, which could have been avoided, was due to the carelessness and disobedience of the soldier.

5.—During the night, an officer made reconnaissance of the Japanese camp across the river, and the combat team crossed at dawn, catching the Japanese by surprise and killing many of them. The entire operation was a success, and the enemy suffered many casualties. The attached Chinese units arrived within 24 hours to take over the position, and several heavy enemy counterattacks were broken up.

One platoon of the combat team found that in crossing the river they were required to make two crossings because of the S-shaped character of the river. While making the second crossing, the platoon came under fire from enemy automatic weapons located on a 20-foot embankment. Two men were wounded on the approach and two more were wounded during a rescue attempt. One of the four soldiers was killed.

Case 23.—Moderately severe perforating wound of the left leg with a compound comminuted fracture of the fibula. This man was on offensive action in a prone position in grass and brush cover when he was struck by a bullet fron an enemy light machinegun at a 125-yard range. The man was able to bandage his own wound and was evacuated. Classified as WIA, second echelon type.

Case 24.—Mild penetrating wound of the right leg. This man was struck under circumstances similar to those of Case 23. This man received treatment within 45 minutes and was classified as WIA, second echelon type.

Case 25.—Multiple, severe penetrating and perforating wounds of the head, the left arm, and the right foot. This man was wounded under circumstances similar to those of Case 23. Two hours after this casualty sustained his injuries, he reached an aid station where he received 6 units of plasma. On the following day, he was treated at the Seagrave Unit No. 2. Classified as DOW, with a 6-day survival. This man was attempting to reach a wounded man, and it is possible that his death could have been avoided if he had waited until more firepower were available.

Case 26.—Severe penetrating and perforating wounds of the right thigh. This man was wounded under circumstances similar to those of Case 23. Classified as WIA, second echelon type.

6.—After the Japanese camp was occupied, a platoon patrol advanced north on the road. A Japanese truck was encountered before cover was available; one American was wounded, and nine Japanese were killed. Numerous other American casualties occurred in the camp area.

Case 27.—Moderately severe penetrating wound of the right arm. This man was on patrol and in a prone position in grass cover along the side of the road when he was struck

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by a fragment from a Japanese hand grenade at a 5-yard range. Classified as WIA, immediate duty type.

Case 28.—Mild laceration of the left temporal region of the head. This man was on defensive action when he was struck by a Japanese rifle bullet. Classified as WIA, immediate duty type.

Case 29.—Moderately severe lacerating wound of the right forearm. This man was on defensive action and was constructing a foxhole when he was struck by a fragment from a 90 mm. mortar shell which exploded at a 10-yard range. Classified as WIA, second echelon type.

Case 30.—Moderately severe penetrating wound of the right side of the neck. This man was sitting in a very shallow foxhole with his head down when he was struck by a fragment from a 90 mm. mortar shell which had a tree burst at a 5-yard range. Classified as WIA, U.S. evacuation type. This casualty might have been avoided if he had constructed a deeper foxhole.

Case 31.—Severe perforating wound of the right forearm. This man, while on defensive action, left his foxhole and was in a standing position when he was struck by a fragment from a 90 mm. mortar shell which had a tree burst at a 5-yard range. Classified as WIA, U.S. evacuation type. This casualty could have been avoided.

Case 32.—Moderately severe laceration of the left hand. This man was on defensive action in a prone position but had not constructed a foxhole. During an enemy counterattack, he was struck by a .25 caliber rifle bullet at an unknown range. Classified as WIA, second echelon type. This casualty might have been avoided if he had taken advantage of protective cover or of a foxhole.

Case 33.—Severe penetrating wound of the abdomen, anteriorly. This man, while under defensive action, was sleeping in a very shallow foxhole when he was struck by a fragment from a 77 mm. artillery shell which had a tree burst at a 5-yard range. This man did not receive any treatment and died within 30 minutes. Classified as DOW. This casualty might have been avoided if he had constructed a deeper foxhole.

Case 34.—Severe perforating wound of the right buttock. This man was sleeping in the same foxhole with Case 33 and was wounded under similar circumstances. Classified as WIA, second echelon type.

Case 35.—Moderately severe penetrating wound of the abdomen, posteriorly. This man was in a prone position in a foxhole when he was struck by a fragment from a 90 mm. mortar shell which had a tree burst at a 2- to 3-foot range Classified as WIA, second echelon type.

Case 36.—Moderately severe penetrating wounds of the right forearm and the right leg. This man was in the same foxhole with Case 35 and was wounded under similar circumstances. Classified as WIA, second echelon type.

7.—During the night of 28 March, sporadic enemy artillery and mortar fire was directed at the perimeter, and three casualties were sustained.

Case 37. Enemy artillery shell made a direct hit in the center of the thorax, posteriorly, and the body was mutilated into three separate pieces. This man was on defensive action in a foxhole which was considered to be too deep and much too large. He was killed instantly. This casualty might have been avoided if the foxhole had been properly constructed.

Case 38.—This man was occupying the same foxhole as Case 37 and sustained at least 30 perforating and penetrating wounds of the thorax, abdomen, and lower extremities. Classified as DOW, with a 30-minute survival period.

Case 39.—Severe penetrating wounds of the left leg. This man was in a foxhole on defensive action when he was struck by a fragment from an enemy 77 mm. shell. Classified as WIA, U.S. evacuation type.

8.—A combat team of 250 men from the 1st Battalion threw up a roadblock at Kauri, 1 mile south of Nhpum Ga, at 1800 hours on 8 April. A strong perimeter was set up, and

two attempts of an enemy food and ammunition train to reach the Japanese lines were repulsed. One American was killed by fire from a U.S. carbine, and another soldier shot himself while cleaning his gun. Two casualties resulted from enemy fire.

On 13 April, one man was killed and one man was wounded while out on patrol. Four other casualties occurred up to 1 May 1944. Two of these casualties were wounded by carbine fire, one was killed by fire from a Thompson submachinegun, and one was wounded by fire from a Browning automatic rifle. During the first 3 weeks in April, 6 of the 10 casualties were caused by U.S. weapons.

Case 40.—Severe perforating wounds of the head. This man, while on defensive action, left his foxhole during the night to investigate a noise. He was killed 10 feet from his foxhole by fire from a U.S. carbine at a few yards range. Classified as KIA. This casualty, due to carelessness, could have been avoided.

Case 41.—Mild laceration of the thorax. This man, while on defensive action, left his foxhole to reach his pack when he was struck by fire from a Japanese supply train. Classified as WIA, immediate duty type. The Americans had opened fire first, and this man did not have time to take protective cover.

Case 42.—Severe perforating wound of the right foot. This man was on offensive action moving in a crouched position toward the Japanese when he was struck by a .25 caliber rifle bullet at an unknown range. Classified as WIA, U.S. evacuation type.

Case 43.—Severe penetrating wound of the right forearm. This man was in a foxhole on defensive action when he was wounded by an accidental discharge of his own rifle. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 44.—Moderately severe perforating wound of the left foot. This man was sitting cleaning his carbine when it accidentally discharged. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 45.—Multiple penetrating and perforating wounds of the chest and abdomen. This man was out on patrol when he was ambushed by the Japanese and was struck by a burst of light machinegun fire at a 10-yard range. Classified as KIA.

Case 46.—Severe perforating wound of the right leg. This man was wounded under circumstances similar to those of Case 45. Classified as WIA, U.S. evacuation type.

Case 47.—Severe perforating wound of the thorax. This man was in a foxhole on defensive action and was awakened by the return of his companion at 0100 hours. This man then left his foxhole and was mistaken for a Japanese and shot with a Thompson submachinegun. Classified as KIA. This casualty could have been avoided.

Case 48.—Moderately severe perforating wound of the right foot. This man, after trading his Thompson submachinegun for a carbine, was engaged in cleaning the carbine when it accidentally discharged. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 49.—Complete traumatic amputation of the right middle finger. This man was cleaning his Browning automatic rifle when it accidentally discharged. Classified as WIA, first echelon type. This casualty could have been avoided.

9.—On 10 May 1944, the 1st Battalion, with the 150th Chinese Infantry attached, bypassed the 3d Battalion, with the 88th Chinese Infantry attached, at Ritpong and proceeded to take the southern airfield at Myitkyina on 17 May. From this time, until they were reformed early in June, the 1st Battalion defended the airfield, with three casualties, details of which follow. Later casualties are not included in this study.

Case 50.—Mild laceration of left thigh. This man, while on offensive action, was wounded by a fragment of a U.S. mortar shell. Classified as WIA, immediate duty type. This casualty could have been avoided.

Case 51.—Mild penetrating wound to the left side of the thorax. This man was riding in a jeep at the airfield when he was hit by a ricochet of an enemy rifle bullet which struck the vehicle. Classified as WIA, first echelon type.

Case 52.—Severe perforating wound of the thorax and penetrating wound of the left arm. This man, while on defensive action, was walking on the airstrip when he was struck by an enemy sniper's bullet at a 15-yard range. Classified as DOW, died 30 hours later while being taken to a hospital.

10.—An American patrol of 18 men had moved 750 yards from the base at Zigyum ferry when the patrol hit a 7-man enemy trail block. Three Americans were wounded, one dying later of his wounds; there were three Japanese casualties.

Case 53.—Moderately severe penetrating wound of the abdomen. This man was on offensive action in a standing position when he was struck by a fragment from a Japanese hand grenade which exploded at a 2-yard range. Classified as WIA, second echelon type. This casualty could have been avoided if he had taken advantage of cover and concealment.

Case 54.—Moderately severe penetrating wound of the left thigh and the hip. This man was wounded under circumstances similar to those of Case 53. Classified as WIA, first echelon type. This casualty could have been avoided.

Case 55.—Severe penetrating wound of the left side of the head and multiple penetrating wounds of the left side of the thorax. This man was on offensive action in a standing position when he was struck by fragments from an enemy hand grenade which exploded at a 3-foot range. Classified as DOW with a 58-hour survival period. This casualty could have been avoided.

11.—The 1st Battalion sustained the following casualties during the period 24–26 May 1944:

Case 56.—Moderately severe penetrating wound of the right forearm. This man was on a defensive position when he was struck by a fragment from a 60 mm. Chinese mortar shell. Classified as WIA, first echelon type. This casualty was due to carelessness on the part of the Chinese forces.

Case 57.—Moderately severe penetrating wound of the left side of the thorax. This man was wounded under circumstances similar to those of Case 56.

Case 58.—Moderately severe penetrating wounds of the right forearm with a compound fracture of the radius. This man was on defensive action when he was wounded by an enemy rifle bullet. Classified as WIA, second echelon type.

Case 59.—Mild penetrating wound of the left side of the thorax. This man was sitting on the ground at the airfield when he was struck by an enemy rifle bullet. Classified as WIA, first echelon type.

Case 60.—Moderately severe lacerating wound of the left side of the thorax. This man was wounded by a fragment from a Japanese 77 mm. artillery shell. Classified as WIA, immediate duty type.

12.—At 1515 hours on 8 June 1944, a six-man patrol attempted to set up a machinegun in the vicinity of the airstrip. They saw the body of a Chinese casualty, and in attempting to reach it they were fired on by two Japanese light machineguns. The first burst took the heel off one man's shoe, grazed another man, and hit another soldier's carbine. After a few minutes of action, one man was killed. It was estimated that two Japanese were killed.

Case 61.—Severe perforating wound of the head. This man, while on offensive action in a prone position in brush cover, attempted to reach his helmet which had fallen off when he was struck by an enemy light machinegun bullet at a 150-yard range. Classified as KIA. This man had killed one of the enemy machinegun crew from the spot where he was hit and apparently did not take advantage of further protective cover.

APPENDIX C

Casualties, 3d Battalion, 5307th Composite Unit (Provisional), Burma Campaign, 15 February–8 June 1944

James E. T. Hopkins, M.D.

In the following pages, the various engagements of the 3d Battalion, 5307th Composite Unit (Provisional), during the Burma campaign are grouped into tactical situations, and casualties are described in the order in which they occurred in combat.

1.—On 28 February 1944 in the region of Nzanga Ga, the I and R (Intelligence and Reconnaissance) Platoon, 3d Battalion, was traveling 6 hours ahead of the main body of troops. The I and R Platoon consisted of 46 men, 4 animals, 4 Browning automatic rifles, and 6 Thompson submachineguns.

At 1000 hours, the platoon was on the trail where it crossed a rice paddy which was overgrown with tall, thick elephant grass, and the first section made contact with the enemy at the village boundary. Since the platoon was under orders not to engage in any fire fights, it withdrew 2 miles north to Lanem Ga where a trail block was set up, and they waited the arrival of the battalion. The enemy force was estimated to be made up of approximately 20 men with rifles, 2 light machineguns, and 1 heavy machinegun. Reconnaissance at a later time showed that the enemy apparently left the area during the night. Only one American casualty was sustained.

Case 1.—Mild laceration of the left side of the face. This man, while on patrol, was firing his M1 rifle from a prone position when he was struck by an enemy .25 caliber light machinegun bullet at an approximate 30-yard range. Classified as WIA, immediate duty type.

2.—On 3 March, the 3d Battalion was moving along the north trail leading into the village of Lagang Ga. The I and R Platoon had already passed through the village and was being followed by several rifle platoons and the Orange and Khaki Columns. As the battalion Headquarters Company of the column passed through the village, a group of Japanese were noted approaching along the south trail along the river bank. Word was passed along the column that the enemy was approaching, and, when they were approximately 50 yards from the Headquarters Company, many of the men in the column opened fire. The party of Japanese consisted of seven men, and they were carrying a litter. The enemy party was protected by a light machinegun. Five of the Japanese were killed instantly by the American fire and two escaped. However, they were killed at a later time. There were no American casualties. The Japanese casualties had multiple wounds inflicted by small arm weapons, and all had died instantly. It was impossible to examine the bodies carefully because of the continuing engagement with the enemy.

3.—Shortly after the encounter just described, the leading elements of the Orange Column contacted a small party of Japanese approaching from the vicinity of Walawbum. A brief fire fight ensued and several of the enemy were killed, but there were no American casualties.

Perimeters were set up, and the entire column dug in for the night. Later in the same day, the I and R Platoon was ordered to leave the area and cross the Numpyck Hka River and protect the right flank of the column as it proceeded toward Walawbum on the following day. The platoon halted at dark and dug in.

At dawn the next morning, the platoon leader took a small group forward about 300 yards and found slightly commanding ground from which the column could receive flank protection until it reached its position along the river opposite Walawbum. The entire I and R Platoon then moved forward and took up its new position.

All of this movement took place at approximately 0700 hours on 5 March. Since it was quite foggy, the visibility was very poor, and the Americans sustained a casualty along their perimeter before they realized that they had been surrounded by approximately 90 Japanese. The platoon leader had available 48 men with 3 Browning automatic rifles and 6 Thompson submachineguns. The ensuing engagement lasted from 0700 hours until 1100 hours when the I and R Platoon withdrew under cover of mortar fire and smoke, leaving approximately 60 Japanese casualties. During the engagement, the platoon had sustained three casualties.

Case 2.—Severe perforating wound of the right lower quadrant of the abdomen and multiple penetrating wounds of the right and the left arm. This man, while on defensive action at the platoon perimeter, was standing gathering camouflage material when he was struck by enemy small arms fired at a range of approximately 50 yards. This man reached the battalion surgeon in approximately 3 hours and received 5 units of plasma and was evacuated by plane 10 hours after receiving his injury. Classified as DOW, with a 10½-hour survival time. This casualty might have been avoided if he had been more alert and had taken advantage of protective cover.

Case 3.—Severe perforating wounds of the left temporal region of the head. This man was on defensive action firing from a prone position in a shallow foxhole when he was struck by fragments from a Japanese mortar shell which had a tree burst at a 25-yard range. He was taken to the battalion surgeon but died within 2 hours. Classified as DOW, with a 2-hour survival time. This casualty might have been avoided if he had worn his helmet and had taken advantage of a deeper foxhole.

Case 4.—Moderately severe penetrating wound of the left forearm. This man was in a position similar to Case 3 and was wounded under similar circumstances. Classified as WIA, first echelon type.

4.—During the encounter between the I and R Platoon and the encircling enemy force, the Orange Column, which had dug in for the night approximately 40 yards from the river, came under enemy mortar fire. Three American casualties were sustained.

Case 5.—Severe penetrating wounds of the left thigh and the thorax. This man was on defensive action, and in charging with a mortar section he moved off the trail to construct a foxhole when he was struck by a fragment from a Japanese knee mortar shell which had a tree burst at a 15-foot range. Classified as KIA, died instantly.

Case 6.—Mild penetrating wound of the right side of the abdomen. This man was in a prone position in a foxhole when he was struck by a fragment from the shell which struck Case 5. Classified as WIA, immediate duty type.

Case 7.—Mild laceration of the abdomen. This man was sitting in the jungle without advantage of any protective cover or a foxhole when he was struck by the shell which struck Case 5. Classified as WIA, immediate duty type.

5.—The Khaki Column remained in the vicinity of the village of Lagang Ga in order to protect the rear of the column as well as the airstrip. No contact had been made with the enemy on 3 March, but at approximately 0630 hours on 4 March the perimeter was struck by an enemy force of approximately 30 men armed with 2 light machineguns, 2 knee mortars, and many rifles. The American troops were engaged in preparing breakfast and were considerably disorganized during the attack. A number of American troops were examining the bodies of five Japanese killed during the previous day. The entire engagement lasted approximately 20 minutes when the Japanese withdrew with at least six KIA casualties. The Americans sustained six WIA casualties.

Case 8.—Severe penetrating wound of the right forearm with a compound fracture of the radius. This man was on defensive action in a prone position with his machinegun when he was struck by an enemy .25 caliber light machinegun bullet. Classified as WIA, second echelon type.

Case 9.—Multiple, moderately severe penetrating wounds of the right and left upper and lower extremities. This man had approximately 100 small fragments in the skin, the

subcutaneous tissues, and the muscles of the upper and lower extremities. He was in a prone position under the same circumstances as Case 8 when he was struck by fragments of an enemy knee mortar shell which burst at a range of approximately 3 yards. Classified as WIA, second echelon type.

Case 10.—Multiple, moderately severe penetrating wounds of the right and left lower extremities. This man was wounded under circumstances similar to those of Case 9. Classified as WIA, first echelon type.

Case 11.—Mild laceration of the left side of the thorax. This man was in a position similar to that of Case 9 when he was struck by a fragment from an enemy hand grenade which exploded at a 3-yard range. Classified as WIA, immediate duty type. This casualty might have been avoided if he had taken advantage of protective cover in a foxhole.

Case 12.—Mild laceration of the head and face. This man was wounded under circumstances similar to those of Case 9. Classified as WIA, immediate duty type.

Case 13.—Moderately severe penetrating wound of the head and severe penetrating wound of the right side of the thorax. This man was on defensive action in a prone position when he was struck by a fragment from an enemy knee mortar shell which had a tree burst. Classified as WIA, first echelon type. This casualty might have been avoided if he had worn his helmet and taken advantage of a foxhole or of other protective cover.

6.—Later in the day on 4 March, the Khaki Column, with all men and animals, moved from its position 200 yards south of Lagang Ga to set up a perimeter on the bank of the river opposite the village of Walawbum. During the afternoon, an extensive mortar barrage was fired into the village, but the enemy force retaliated with approximately 20 mortar shells.

During 5 March, there were sporadic artillery exchanges, but there were no American casualties. However, during the morning and early afternoon of 6 March, the enemy expended about 200 mortar and artillery shells into the Orange Combat Team area and the Americans had three minor casualties. During the late afternoon, the enemy made a sudden attack in force along the river side of the American perimeter. It was necessary for the enemy to approach the river by crossing 60 yards of flat, brush-covered terrain, at least 10 feet below the fairly flat jungle-covered terrain, occupied by the American force. Very few of the enemy troops were allowed to reach the river.

During this encounter of the Orange Combat Team with the enemy on 4 through 6 March, approximately 400 American troops were engaged and only 4 slightly WIA casualties were sustained. Approximately 1,000 Japanese troops were engaged, and it was estimated that they had at least 400 KIA casualties.

Case 14.—Slight penetrating wound of the right thigh. This man was on defensive action sitting in a foxhole when he was struck by a fragment of a Japanese mortar which had a tree burst of a 20- to 30-yard range. Classified as WIA, immediate duty type. This casualty might have been avoided if he had taken advantage of a prone position in his foxhole.

Case 15.—Moderately severe perforating wound of the right forearm. This man was walking on patrol when he was struck by a Japanese rifle bullet. Classified as WIA, immediate duty type.

Case 16.—Moderately severe perforating wound of the left leg. This man was on defensive action in a prone position in a foxhole with his lower extremities unprotected. He was struck by a fragment from a Japanese mortar shell which had a tree burst directly over his foxhole. Classified as WIA, first echelon type and required 1 month of hospitalization.

Case 17.—Moderately severe penetrating wound of the right side of the head. This man was in the same foxhole and was wounded under the same circumstances as Case 16. Classified as WIA, immediate duty type. This casualty could have been avoided if he had taken advantage of the protection afforded by his helmet.

7.—During the time that the Orange Combat Team was supporting the I and R Platoon, the Khaki Combat Team rested along the trail at Lagang Ga. Though no active

fighting took place and no Japanese artillery shells landed in the Khaki Combat Team area, one casualty was sustained.

The Khaki Column bivouacked during the night of 5 March in the area occupied by the Orange Column. The Khaki Combat Team remained in this area covering the Orange Column's supply trail until midafternoon on 6 March. A few 77 mm. artillery shells fell in the area, and two men were wounded. After leaving the bivouac area, the Khaki Column attempted to reach the Orange Combat Team by traveling through the jungle to the left of the main trail. However, this operation was unsuccessful, and the men became lost and wandered in the jungle for 8 hours. During this time, 4 men were wounded and 1 was killed by contact with boobytraps which had been set by the Orange Combat Team. Finally, both columns were reunited, and they were relieved by Chinese troops.

Case 18.—Slight lacerations of the left side of the thorax. This man was on patrol walking along an open trail when he was struck by an enemy rifle bullet at a range of approximately 200 yards. Classified as WIA, immediate duty type.

Case 19.—Moderately severe perforating wound of the left hand. This man, while on defensive action guarding a supply line, was in a prone position. He was wounded by a fragment from an enemy 77 mm. artillery shell which fell 20 yards from his position. Classified as WIA, first echelon type, and required 30 days of hospitalization. This casualty might have been avoided if he had taken advantage of protective cover or of a foxhole.

Case 20.—Mild lacerations of the thorax. This man was wounded under circumstances similar to those of Case 19. Classified as WIA, immediate duty type.

Case 21.—Multiple penetrating wounds of the lower extremities. This man while on a night march through thick jungle, was attempting to reach the Orange Combat Team when he walked into a boobytrap previously set up by that unit. Classified as WIA, immediate duty type.

Case 22.—Multiple perforating wounds of the lower extremities. This man was wounded under circumstances similar to those of Case 21. Classified as WIA, immediate duty type.

Case 23.—Multiple, mild penetrating wounds of the lower extremities and of the face. This man was wounded under circumstances similar to those of Case 21. Classified as WIA, immediate duty type.

Case 24.—Severe, multiple wounds of various body regions. This man was wounded under circumstances similar to those of Case 21 and several days elapsed before his body was found. Classified as KIA.

Case 25.—Multiple penetrating and perforating wounds of the thorax and the upper and lower extremities. This man was wounded under circumstances similar to those of Case 21. Classified as WIA, second echelon type.

8.—During the period from 7 March to 31 March, the 3d Battalion was engaged in marching through very rugged and mountainous terrain toward the Japanese-held road at Inkangahtawng 12 miles north of Kamaing. On 25 March, the Khaki Combat Team of the 3d Battalion and members of the 2d Battalion reached the area and set up a roadblock. The 2d Battalion became engaged with the enemy, and after inflicting many casualties they withdrew because of a threatened encirclement. The Khaki Combat Team did not take a very active part in the fighting, and they withdrew with the 2d Battalion to Sharaw. A landing strip was constructed here for the evacuation of U.S. wounded.

On the following day, the retreat was continued through Manpin toward Auche. The Orange Combat Team had been holding the trail open at Manpin. On 26 and 27 March, the Orange I and R Platoon fought two skirmishes with the forward elements of a Japanese battalion advancing from Kamaing toward Warawng Ga by another trail. The 2d and 3d Battalions reached Auche during the afternoon of 27 March. The following casualties were sustained:

Case 26.—Mutilation of the head and traumatic amputation of the right lower extremity. This man was watching a supply drop for the Chinese when he was struck by a case of

mortar ammunition which had become separated from its parachute. Classified as KIA. It had not been planned to include this casualty in the records of this casualty survey, but unfortunately he was recorded in the tabulation of multiple wounds due to miscellaneous causes.

Case 27.—Minor, severe penetrating wounds of the left shoulder and lacerations of the left leg. This man was on defensive action retreating from bivouac area when he was injured by a fragment from an enemy 77 mm. artillery shell at an unknown range. Classified as WIA, first echelon type.

Case 28.—Mild penetrating wound of the left buttock. This man was wounded under circumstances similar to those of Case 27. Classified as WIA, immediate duty type.

Case 29.—Multiple, severe penetrating and perforating wounds of the right lower extremity and a severe penetrating wound of the right lower quadrant of the abdomen. This man was cleaning his M1 rifle when he was struck by a burst of fire from a rifle being cleaned by another enlisted man at a 10-foot range. Classified as DOW, with a 1-hour survival. This casualty could have been avoided.

Case 30.—Severe perforating wound of the thorax. This man was a member of a five-man patrol which had just come out of dense jungle along a narrow trail into fairly open terrain. Another patrol from the 2d Battalion was sighted 50 yards ahead on the trail. One of the men of this patrol opened fire with his rifle. Classified as KIA. This casualty could have been avoided since the light tan British-type coveralls which this casualty was wearing probably confused the members of the other patrol.

Case 31.—Mild perforating wound of the right thigh. This man was a member of a 60 mm. mortar squad and was wounded by an accidental discharge of a defective propelling charge. Classified as WIA, immediate duty type.

9.—During the period from 7 March to 31 March 1944, there were approximately 450 Americans engaged against an approximated equal number of the enemy. The Americans sustained a total of 6 casualties, and the Japanese sustained a total of from 95 to 145 casualties.

On the morning of 28 March, the 3d Battalion arrived at Hsamshingyang with the mission of supplying the 2d Battalion at Nhpum Ga and of keeping the trail open for the evacuation of the wounded. On 28 March, the 2d Battalion was engaged by the enemy, and they evacuated their casualties through the 3d Battalion during the next 3 days.

On 31 March, patrols could not reach the 2d Battalion, and the Orange Combat Team was ordered to open the trail. During the next 6 days, their attempts were unsuccessful, and the Khaki Combat Team was called on to take over the job.

During the period of 1 through 6 April, while the Orange Combat Team was engaged in attempting to lift the Japanese-held trail block, 36 American casualties were sustained of which 6 were KIA, 2 were DOW, and 28 were WIA. The enemy sustained approximately 200 casualties during this same period.

Case 32.—Severe perforating wound of the right lower quadrant of the abdomen. This man was a member of a five-man patrol and was in a kneeling position furnishing cover fire for another scout when he was struck by a Japanese rifle bullet at a 20-yard range. Classified as WIA, first echelon type, and was returned to combat duty within 7 weeks. This casualty might have been avoided if he had taken advantage of better cover and if he had been more cautious.

Case 33.—Severe perforating wound of the left side of the face. This man was on patrol duty advancing on a steep trail flanked by thick jungle and bamboo. He was struck by an enemy rifle bullet at a range of approximately 10 to 20 yards. The battalion surgeon put a tight compress over the mutilated left side of the face, and the casualty walked 1 mile to the regimental aid station. He died during the night. Classified as DOW, with an 18-hour survival.

Case 34.—Severe perforating wound of the left foot. This man was a member of a patrol and was wounded by an enemy rifle bullet at an unknown range. Classified as WIA, U.S. evacuation type.

Case 35.—Severe penetrating wound of the right thigh. This man was on offensive action firing at the enemy from a sitting position when he was wounded by a .25 caliber rifle bullet at a 30-yard range. Classified as WIA, second echelon type, and returned to duty within 3 months.

Case 36.—Moderately severe perforating wound of the right arm. This man was on patrol duty when the patrol encountered a Japanese trail block. The lead scout warned the others to take cover along the side of the trail. The enemy forces opened fire with a light and a heavy machinegun. This man was hit by an enemy light machinegun, but he continued to fire his weapon after being wounded. Classified as WIA, second echelon type. It is noteworthy to see that this man continued in combat even after being wounded and then walked 3 to 4 miles to the airstrip before he was evacuated.

Case 37.—Severe penetrating wound of the right thigh. This man was wounded under circumstances similar to those of Case 36. Classified as KIA.

Case 38.—Severe, multiple penetrating wounds of the right and left lower extremities and a perforating wound of the thorax. This man was wounded under circumstances similar to those of Case 36. The first burst of fire had wounded this soldier in the legs, and as a friend was pulling him to safety he was killed by a bullet through the chest. Classified as KIA.

Case 39.—Mild laceration of the right arm. This man was in a crawling position when he was struck by a ricochet of a .25 caliber rifle bullet. Classified as WIA, immediate duty type.

Case 40.—Mild laceration of the left inguinal region. This man was working with a mortar squad, during preparation for an infantry attack, when he was struck by a stray .25 caliber bullet. He was in a sitting position with no protective cover. Classified as WIA, immediate duty type. This casualty might have been avoided if the mortar squad had taken advantage of defensive cover.

Case 41.—Severe perforating wound of the thorax. This man, while on defensive action, was a member of a group of about 10 men who were bunched along the trail 30 yards from the enemy roadblock. An enemy knee mortar shell exploded 5 yards in back of the group on a slight elevation along the side of the trail. In addition to this casualty, seven others were injured. Classified as KIA. This casualty, as well as the following seven cases, could have been avoided if they had taken advantage of dispersion and of protective cover.

Case 42.—Multiple penetrating and perforating wounds of the neck and of the upper and lower extremities. Classified as WIA, first echelon type.

Case 43.—Multiple perforating wounds of the upper and lower extremities. Classified as WIA, first echelon type.

Case 44.—Multiple perforating wounds of the upper and lower extremities. Classified as WIA, U.S. evacuation type.

Case 45.—Mild perforating wound of the thorax. Classified as WIA, immediate duty type.

Case 46.—Mild penetrating wound of the left shoulder. Classified as WIA, immediate duty type.

Case 47.—Multiple penetrating wounds of the head and the thorax. Classified as WIA, immediate duty type.

Case 48.—Severe penetrating wound of the head. Classified as WIA, U.S. evacuation type.

Case 49.—Multiple, severe wounds of the thorax and the abdomen. This man was on offensive action and was walking without advantage of protective cover when he was struck by a burst of fire from an enemy light machinegun at a 10-yard range. Classified as KIA. This casualty might have been avoided. Cases 49 and 50 were providing protective fire for a man with a flamethrower. They were at the farthest part of the advance when they became careless and stepped from the jungle cover onto the trail where both men were shot.

Case 50.—Severe perforating wounds of the thorax and the right upper extremity. This man was wounded under circumstances similar to those of Case 49. Classified as WIA, U.S. evacuation type.

Case 51.—Mild lacerating wound of the right shoulder. This man was in a prone position behind a tree when he was struck by a fragment from a Japanese hand grenade at a 5-yard range. Classified as WIA, immediate duty type.

Case 52.—Mild laceration of the left forearm. This man was in a prone position when he was struck by a .25 caliber Japanese rifle bullet, at an unknown range. Classified as WIA, immediate duty type.

Case 53.—Moderately severe perforating wound of the abdomen. This man was walking on defensive action when he was struck by an enemy sniper's bullet at a 60-yard range. Classified as WIA, second echelon type. This casualty might have been avoided if he had taken advantage of protective cover. The enemy sniper had been active in this area for some time, and the men had been warned to stay out of open areas.

Case 54.—Mild laceration of the left arm. This man was in a prone position in a foxhole when he was struck by a .50 caliber machinegun bullet from a U.S. P-57 during a strafing attack. Classified as WIA, immediate duty type. Better air-ground communications would have prevented this accident.

Case 55.—Severe perforating wound of the abdomen. This man was sitting in a very shallow foxhole with his upper torso exposed when he was wounded under circumstances similar to those of Case 54. This man received plasma within 5 minutes after being injured and was then evacuated 4 miles by litter carry. He died approximately 24 hours after being injured. Classified as DOW, with a 24-hour survival time. This casualty might have been avoided if he had taken advantage of more complete protection.

Case 56.—Moderately severe lacerating wounds of the left forearm. This man was in a prone position on offensive action when he was struck by an enemy rifle bullet. Classified as WIA, immediate duty type.

Case 57.—Moderately severe penetrating wound of the right shoulder. This man was in a prone position on offensive action when he was struck by an enemy sniper's bullet at a range of approximately 40 yards. The advance had stopped, and the man was attempting to reach an old Japanese foxhole. He was injured as he was entering the foxhole. Classified as WIA, first echelon type. This casualty might have been avoided if he had taken advantage of protective cover instead of exposing himself to sniper fire as he crawled over the ground to the foxhole.

Case 58.—Moderately severe perforating wound of the right arm. This man was in a prone position on offensive action when he was struck by a bullet from a Japanese light machinegun at a 30-yard range. Classified as WIA, first echelon type, and returned to duty within 30 days.

Case 59.—Severe penetrating wounds of the head. This man was in a prone position in a shallow foxhole waiting for the mortar barrage to lift when he was struck by a fragment from a 50 mm. U.S. mortar shell which had a tree burst at a range of approximately 15 yards. Classified as WIA, U.S. evacuation type. This man's helmet probably saved his life. The mortar was being fired from a position too far back of the frontline.

Case 60.—Mild penetrating wound of the right leg. This man was wounded under circumstances similar to those of Case 59. Classified as WIA, immediate duty type.

Case 61.—Mild laceration of the left leg. This man was walking on offensive action when he was struck by an enemy rifle bullet at a range of approximately 30 to 100 yards. Classified as WIA, immediate duty type.

Case 62.—Mild laceration of the left shoulder. This man was sitting in a shallow foxhole near the air station when he was struck by a fragment from a Japanese knee mortar which had a tree burst directly overhead. Classified as WIA, immediate duty type. This casualty might have been avoided if he had taken advantage of a prone position in the foxhole.

Case 63.—Multiple, moderately severe wounds of the head. This man was wounded under circumstances similar to those of Case 62. Classified as WIA, immediate duty type. This casualty might have been avoided if he had worn his helmet and had been in a prone position.

Case 64.—Mild penetrating wounds of the right upper extremity. This man was in a prone position in a foxhole when he was wounded by fragments from a U.S. 60 mm. mortar shell which exploded at a distance of 3 feet from the edge of the hole. Classified as WIA, first echelon type.

Case 65.—Mild penetrating wound of the head. This man was in a prone position on offensive action when he was wounded by fragments from a Japanese hand grenade which exploded at a 2- to 3-yard range. Classified as WIA, immediate duty type.

Case 66.—Severe penetrating wound of the thorax. This man, while on defensive action, was standing on a trail in a known previous line of fire near the front perimeter when he was hit by a .25 caliber rifle bullet at a range of approximately 200 yards. Classified as KIA. This casualty might have been avoided if the man had not engaged in sightseeing and if he had heeded the warning about the enemy's line of fire.

Case 67.—Severe perforating wound of the head. During the change of guard at night, this man sat up in his foxhole. The battalion veterinarian, thinking the soldier was a Japanese, shot him with his .45 caliber pistol. Classified as KIA. This casualty could have been avoided.

10.—On 4 April, the Khaki Combat Team was ordered to bypass the Japanese resistance on the Nhpum Ga trail and to make a right flank attack on the Japanese at the northeast sector of the village where another trail led into the area. After considerable difficulty in passing through the jungle, the combat team arrived in the vicinity of the village at approximately 1600 hours. While advancing up the trail, the three lead scouts were wounded by a burst of Japanese machinegun fire. These men advanced into an ambush without proper reconnaissance or preparation. All other attempts of the Americans to advance were repulsed.

On 5 April, after a quiet night without attack from the Japanese, the combat team advanced along the trail. However, heavy fire from the enemy light machinegun prevented any flanking movement, and the combat team retired from the area.

Case 68.—Severe perforating wound of the head. This man was a lead scout on patrol and was walking up a trail when he was struck by a bullet from an enemy light machinegun. Classified as KIA. This casualty might have been avoided if different tactics had been adopted.

Case 69.—Moderately severe penetrating wound of the left thigh. This man was wounded under circumstances similar to those of Case 68. Classified as WIA, first echelon type.

Case 70.—Severe perforating wound of the neck. This man was wounded under circumstances similar to those of Case 68. Classified as DOW, with a 7-hour survival time. This casualty might have been avoided if he had not attempted to reach Case 69. He should have taken advantage of protective cover until the offensive action could have been properly organized.

Case 71.—Traumatic amputation of the right third finger. This man was wounded under circumstances similar to those of Case 68. Classified as WIA, first echelon type.

Case 72.—Moderately severe laceration of the right thigh. This man was on offensive action and advancing through thick jungle in a low crouched position when he was struck by an enemy light machinegun bullet at a range of approximately 40 yards. Classified as WIA, first echelon type.

Case 73.—Moderately severe perforating wound of the right leg. This man was advancing in a crouched position through thick jungle cover when he was struck by an enemy light machinegun bullet. This man was seen by the battalion surgeon 15 minutes after he was injured, but before that time he had not received any first aid nor had a tourniquet been

applied to his leg. Classified as DOW, with a 40-minute survival time. This casualty could have been avoided if a tourniquet had been applied to his leg.

Case 74.—Minor laceration of the right shoulder. This man was advancing in a crouched position on offensive action when he was struck by an enemy light machinegun bullet. Classified as WIA, immediate duty type.

11.—On 7 April, the Khaki Combat Team took over the perimeter of the Orange Combat Team. The latter team was dispatched on a wide flanking movement to the left of the main trail. Their mission was to cut the Japanese supply line south of Nhpum Ga. This maneuver was not successful because of difficult terrain and supply shortages.

During the period of 7 through 9 April, the Khaki Combat Team had numerous contacts with the enemy forces. The heaviest part of the offensive during 8 April was carried out by the I and R Platoon of Headquarters Company and the 2d Platoon of I Company. All of the positions taken on 7 April were given up because of the high ground held by the Japanese. Five separate attacks were organized during the day. Both 60 and 81 mm. mortars were used to give a barrage of about 400 shells preceding each attack. Much of the fighting took place with only a few yards separating the advance elements of the approaching forces. The fighting throughout most of the day was up steep terrain through closely growing bamboo and thick jungle growth.

Case 75.—Severe penetrating wound of the left forearm with a compound fracture of the left radius. This man, while on offensive action in a prone position, crawled into the fire lane of a Japanese light machinegun. He was wounded at an approximate 60-yard range. Classified as WIA, second echelon type. This casualty might have been avoided if he had stayed out of the known machinegun lane.

Case 76.—Mild penetrating wound of the right arm and multiple penetrating wounds of the left lower extremity. This man was wounded under circumstances similar to those of Case 74. Classified as WIA, first echelon type.

Case 77.—Mild laceration of the left hand. This man was wounded under circumstances similar to those of Case 75. Classified as WIA, immediate duty type.

Case 78.—Severe perforating wound of the thorax. This man was on offensive action and in a crawling position during advancement against the enemy when he was hit by a burst of fire from a Japanese light machinegun at a 100-yard range. Classified as DOW, with a 1½-hour survival time.

Case 79.—Moderately severe penetrating wound of the right hand. This man was on offensive action and was standing throwing a grenade when he was struck by a fragment from a Japanese hand grenade at a range of approximately 10 feet. Classified as WIA, first echelon type.

Case 80.—Severe penetrating wound of the right side of the head. This man was on offensive action and was carrying a radio. The platoon leader informed him that they were entering a danger zone, and, as the soldier was attempting to assume the prone position, he was struck by a bullet from a Japanese .25 caliber rifle at a 40-yard range. Classified as KIA.

Case 81.—Severe penetrating wound of the right side of the head. This man was walking to the left of the trail toward the enemy line in a known fire lane when he was struck by an enemy light machinegun bullet at a 50-yard range. Classified as WIA, U.S. evacuation type. This casualty might have been avoided if he had taken advantage of protective cover and if he had heeded the previous warning in regard to the fire lane.

Case 82.—Mild laceration of the left hand. This man was wounded under circumstances similar to those of Case 81. Classified as WIA, immediate duty type.

Case 83.—Severe perforating wound of the thorax. This man was on offensive action and his platoon had just been relieved and was going into position for flank protection when he was struck by a .25 caliber bullet at a 75- to 100-yard range. He was in a prone position. Classified as DOW, with a 2-hour survival time.

Case 84.—Severe perforating wound of the thorax. This man was on offensive action advancing in a crouched position when he was struck by a .25 caliber rifle bullet at a 20-yard range. Classified as WIA, second echelon type.

Case 85.—Severe penetrating wound of the right leg with a compound comminuted fracture of the right tibia. This man was a radio operator and was occupying a shallow foxhole 50 yards in front of the perimeter and 100 yards in back of the advancing troops. The foxhole had been dug by the Japanese and had a log in front and in back. A light machinegun bullet passed through the log and wounded this man. Classified as WIA, second echelon type. This casualty might have been avoided if he had not occupied this foxhole which was in a known lane of machinegun fire.

Case 86.—Mild penetrating wound of the right thigh. This man was the lead scout of his platoon and in a crouched position when he was struck by a fragment from an enemy hand grenade which had a tree burst of a 5-foot range. Classified as WIA, first echelon type.

Case 87.—Mild laceration of the head and face. This man was in a prone position behind a tree when he was struck by a fragment from an enemy hand grenade which exploded at a range of approximately 5 feet. Classified as WIA, immediate duty type.

Case 88.—Mild laceration of the upper part of the left leg. This man was wounded under circumstances similar to those of Case 86. Classified as WIA, immediate duty type.

Case 89.—Mild penetrating wound of the left side of the face. This squad leader was standing behind a tree when he was struck by numerous fragments from a Japanese hand grenade which exploded at a 2-yard range. Classified as WIA, immediate duty type. This casualty might have been avoided if he had taken advantage of a prone position.

Case 90.—Moderately severe penetrating wound of the left hand. This man was wounded under circumstances similar to those of Case 89. Classified as WIA, first echelon type.

Case 91.—Mild laceration of the right hand. This man was in a prone position of a shellhole when he was struck by a fragment from a Japanese hand grenade at a 5- to 10-yard range. Classified as WIA, immediate duty type.

Case 92.—Severe penetrating wound of the left arm with a compound comminuted fracture of the elbow region. This man was in a prone position firing at a Japanese light machinegun crew when he was struck by an enemy machinegun bullet at a range of approximately 30 yards. Classified as WIA, U.S. evacuation type. This casualty might have been avoided if he had not occupied a known lane of machinegun fire.

Case 93.—Multiple, moderately severe penetrating wounds of the head and the right upper and lower extremities. This man was on offensive action and delivering Browning automatic rifle fire from a shellhole when a Japanese hand grenade burst at a 2-yard range. Despite his multiple wounds, this man continued to deliver effective fire against the enemy light machinegun crew. Classified as WIA, U.S. evacuation type.

Case 94.—Multiple penetrating wounds of the left lower extremity. This man was in a prone position when he was struck by a fragment from an enemy hand grenade at a 2-yard range. Classified as WIA, first echelon type.

Case 95.—Moderately severe perforating wound of the abdomen, posteriorly. This man was on offensive action and was crawling forward when he exposed himself to enemy rifle fire by crawling over a slight elevation on the ground. Classified as WIA, second echelon type. This casualty might have been avoided if he had circled around, rather than crawled over, the elevation on the ground.

Case 96.—Moderately severe penetrating wound of the right forearm. This man was on offensive action and was talking in a crouched position into attack when he made an excessive amount of noise in going through a clump of bamboo. He was wounded by fire from a Japanese sniper's rifle. Classified as WIA, second echelon type. This casualty might have been avoided.

Case 97.—Mild penetrating wound of the right side of the neck. This man was crawling back to the command post for ammunition when he was wounded by fragments from an enemy hand grenade which exploded within a few feet of his position. Classified as WIA, immediate duty type.

Case 98.—Mild penetrating wound of the right hand. This squad leader was crawling toward the enemy lines when he was struck by a fragment from an enemy hand grenade at a 5-yard range. Classified as WIA, immediate duty type.

Case 99.—Severe perforating wound of the abdomen and a moderately severe penetrating wound of the thorax. This man was on offensive action and was scouting about in a dense clump of bamboo when he was struck by the first burst of Japanese heavy machinegun fire at a 25- to 30-yard range. Classified as DOW, with a 24-hour survival time.

12.—On 8 April, an unfortunate accident occurred. A 60 mm. mortar shell scored a direct hit on a headquarters company heavy machinegun crew. One man survived, two died of wounds, and a fourth was killed instantly. A prior air and artillery barrage had cleared away the bamboo and jungle growth for approximately 100 yards along the trail, and the U.S. mortars were set up in this area. The frontline of the perimeter was 200 yards in front of the mortars. At this distance on the left of the trail, there was a large hole in which was placed a heavy machinegun squad. Across the trail was another hole occupied by the battalion commander and the officer directing fire. A mortar barrage was planned and the 81 mm. mortars were zeroed in. It was then decided to add the 60 mm. mortars to the barrage. The initial range was 350 to 400 yards. Following the primary zeroing round, a second round was requested, and subsequent investigation revealed that despite the usual precaution this round fell short and landed on the machinegun emplacement. After this accident, the 60 mm. mortar was used only as a frontline weapon.

Case 100.—Multiple, moderately severe penetrating wounds of the neck, thorax, and upper and lower extremities. This man was crouched in a left posterior corner of the machinegun hole when the 60 mm. mortar shell exploded at an approximate 4-foot range. Classified as WIA, second echelon type.

Case 101.—Multiple penetrating and perforating wounds of the abdomen and lower extremity. This man was wounded under circumstances similar to those of Case 100. Classified as DOW, with a 12-hour survival time.

Case 102.—Multiple penetrating wounds of the face, abdomen, and upper and lower extremities. This man was wounded under circumstances similar to those of Case 100. Classified as DOW, with a 2-month survival time.

Case 103.—Large mutilating wounds of the right side of head and body with compound comminuted fractures of right arm and leg. This man was in very close proximity to the 60 mm. mortar shell when it exploded. Classified as KIA.

13.—On 9 April 1944, an early morning patrol was sent forward from the Khaki Combat Team perimeter. In the area where the resistance had been the strongest, the patrol encountered only one live Japanese. He appeared to be in a dazed condition and was wandering about carrying the arm of another soldier which had been cleanly cut off below the elbow. In his attempt to escape, he was killed.

The Khaki Combat Team Rifle Platoon soon moved into the area and made contact with the 2d Battalion without meeting any enemy resistance. The 2d Battalion had been surrounded by elements of one Japanese battalion reinforced with a heavy weapons company which had opposed all rescue attempts. The 2d Battalion had been subjected to 11 days of fanatical rushes by the enemy from all sides of their perimeter and daily pointblank artillery fire from two mountain artillery pieces (nicknamed "whiz bangs") and mortar fire. A combat team from the 1st Battalion, which had been on a flanking mission, entered the village somewhat later. The long train of wounded men was quickly moved to the airstrip, 5 miles away.

The Orange Combat Team arrived from its unsuccessful flanking movement, and a strong perimeter was set up about the village. Strong points were placed along the trail to keep the 5-mile supply route open.

Elements of the 5307th Composite Unit (Provisional) remained in this area until 24 April, when the entire area was turned over to the Chinese troops. Constant patrol action

was carried out during this period. The Japanese had withdrawn south along the trail to Auche and Warawng.

Case 104.—Severe penetrating wound of the left leg. This man was sitting on the edge of a previous Japanese foxhole when he was struck by a fragment from an enemy artillery shell which exploded at a 5-yard range. Classified as WIA, second echelon type.

Case 105.—Multiple penetrating wounds of the right and left lower extremities and the thorax. This man was on patrol activity when he walked into a U.S. boobytrap armed with a hand grenade. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 106.—Moderately severe perforating wound of the left arm and penetrating wound of the thorax. This man, a member of a five-man patrol, had moved from the protective cover of the tall grass onto the trail. He was struck by fire from an enemy machinegun at a range of approximately 75 yards. Classified as KIA. This casualty could have been avoided if he had refrained from stepping into the trail in this close proximity to the enemy.

Case 107.—Mild laceration of the thorax. This man was a member of the same patrol as Case 106 and became very nervous after the patrol leader was struck. In his attempt to crawl to the rear, he was struck by fire from a Japanese sniper's rifle. Classified as WIA, immediate duty type. This casualty could have been avoided if he had remained at his post.

Case 108.—Moderately severe penetrating wound of the left lower extremity. This squad leader, becoming very excited when the enemy contact was made, was struck by fire from an enemy sniper's rifle bullet at a 60-yard range. Classified as WIA, first echelon type.

Case 109.—Severe perforating wound of the right leg. This man was cleaning his M1 rifle and forgot to remove the cartridge in the clip; the gun was accidentally discharged. Classified as WIA, U.S. evacuation type. His wound necessitated amputation of the leg. This casualty could have been avoided.

Case 110.—Severe perforating wound of the left leg. This man was on patrol and thought he heard a noise. He then proceeded to arm his pistol but forgot to release it to safety after placing it in his holster. A few minutes later, there was an accidental discharge of the weapon. Classified as WIA, second echelon type. This casualty could have been avoided.

14.—The entire regiment (5307th Composite Unit (Provisional)) was in the vicinity of Naubum on the Tanai Hka River from 25 to 30 April. After reorganization at Hsamshingyang, plans were drawn up for the capture of the airfield at Myitkyina. Because of its reduced strength, the 2d Battalion was to be held in regimental reserve. The 3d Battalion with approximately 350 men in the Orange Combat Team and 250 men in the Khaki Combat Team was to work with the 88th Infantry Regiment and the 1st Battalion, with the 150th Infantry Regiment of the Chinese Army. The Chinese troops had been trained by Americans and were equipped with American weapons. The majority of American troops were in very poor physical condition after their 3 months' stay in Burma. Many had medical conditions which under ordinary circumstances would have required hospitalization.

The 3d Battalion followed by the Chinese 88th Infantry Regiment left Naubum on 30 April for the very difficult trek over the 6,034-foot high Jaupadu Bum mountain range leading to the Myitkyina Valley. In spite of many alarms, no contact was made with the enemy by the King Force (the 3d Battalion plus the Chinese 88th Infantry Regiment) until it reached Ritpong, a typical Kachin hill valley 50 miles north of Myitkyina. The north trail into the village rises 500 feet within 500 yards, and the south trail runs over a gentle ridge with steep sides. Therefore, the terrain presented an ideal defensive position for the enemy.

On 6 May, the 3d Battalion cut a trail through the jungle to the left of the village and blocked the south trail. The Chinese closed in on the north trail and attacked on 7 May, finally entering the village on 10 May. The Japanese garrison of one company had been destroyed, and one wounded Japanese who remained described a small party of about 30 men who escaped.

Between 7 and 10 May 1944, about 700 U.S. troops were engaged in the action described, though never more than 3 platoons were involved at any one time. Of the approximately 3,000 Chinese troops engaged, never more than 500 were used at one time. There were between 200 and 300 Japanese in the opposing forces. They sustained about 185 casualties, and the Chinese sustained 30 KIA and 100 WIA.[1]

The details of the five U.S. troops WIA, one of whom later died of his wounds, are as follows:

Case 111.—Severe penetrating wound of the right side of the thorax. This man was on defensive action in a prone position in a foxhole when he was struck by a stray Japanese bullet at a 100-yard range. Classified as DOW, with a 4-day survival time.

Case 112.—Severe perforating wound of the right side of the neck. This man was on offensive action and was bringing up several men to support the light machinegun which his platoon leader had set up. He knew that snipers had been shooting into this general area for the past 15 minutes. While moving just to the right of the trail with very poor jungle cover, he turned to give a command and was struck by a .25 caliber rifle bullet at a 70-yard range. Classified as WIA, U.S. evacuation type. This casualty might have been avoided if he had taken advantage of protective cover and concealment.

Case 113.—Moderately severe perforating wound of the thorax. This man was on offensive action and advancing in a crouched position when he was struck by a .25 caliber rifle bullet at a 100-yard range. Classified as WIA, second echelon type. This casualty might have been avoided if he had taken advantage of protective cover and concealment.

Case 114.—Moderately severe perforating wound of the right thigh. This man was in a prone position in the midst of jungle cover firing at the enemy when he was struck by a heavy machinegun bullet at a 75-yard range. Classified as WIA, second echelon type.

Case 115.—Penetrating wound of the left foot and multiple penetrating wounds of the left leg. This man was on defensive action and was withdrawing from contact with the enemy when he was struck by fragments from 90 mm. Japanese mortar shell which burst 1 yard in front of him. Classified as WIA, second echelon type.

15.—After leaving Ritpong, the I and R Platoon of the Orange Combat Team managed to cover 12 miles in approximately 24 hours and approached Tingkrukawng on 13 May 1944. Their route had led up a steep hill on a razorback trail which threaded its way through thick

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[1] During this 4-day engagement, the Chinese, according to their regimental surgeon, sustained between 25 and 30 casualties (KIA). It was never possible to obtain any further information.

No records are available on the Chinese wounded, but the writer of this chapter saw the 100 who were treated in the 42d Portable Surgical Hospital located 400 yards north of the village and can make a fairly accurate statement concerning them.

Mortar and grenade fragments accounted for at least 80 percent of the casualties and machinegun and rifle bullets for the remainder. About half of the mortar casualties seemed caused by Chinese fire.

Local anesthesia was used in all cases, supplemented by Penthothal sodium (thiopental sodium) in two abdominal operations.

No skull fractures or brain wounds were treated, though 10 percent of the casualties had head injuries. One casualty had a severe perforating mortar wound of the right side of the neck, laterally, with the exit wound through the distal third of the tongue. This man died in 72 hours, without surgical intervention, and with uremia as the most prominent feature. The entire end of the tongue was necrotic before his death.

No sucking thoracic wounds and very few penetrating wounds were seen, though thoracic wounds were found in 20 percent of the casualties. One casualty with a wound 6 cm. in diameter over the right scapula had no evidence of penetration of the thoracic cavity. He died after debridement.

Three casualties with abdominal wounds died of hemorrhage and shock a few minutes after they arrived at the aid station, and two others, apparently with penetrating wounds, were operated on, but no perforations were found. A sixth casualty survived severe peritonitis without surgical intervention; treatment consisted of sulfadiazine and a liquid diet. He had a foul wound of the left lower quadrant of the abdomen, in which the descending colon was visible. No other penetrating wounds were observed. Twenty percent of the casualties had abdominal wounds.

No amputations of the lower extremities were performed, and only one hand and one arm were removed. Extremity wounds were found in 50 percent of the casualties, and at least 15 compound fractures of the lower extremities were observed.

Of the 100 Chinese wounded in action, 47 were considered litter cases. They were carried 10 miles to a jungle strip at Arang, whence they were evacuated by plane. The majority had been on some form of sulfonamide therapy for 3 days.

bamboo and jungle growth. As the platoon came down the trail to where it gave a view of the village, the first scout motioned for his platoon to come to a halt. He saw about 40 men bunched on the trail 50 yards distant on the far side of the village. Their helmets were decorated with parachute cloth, such as the Chinese troops often wore. One of these Japanese gave the Chinese greeting and the American scout replied. Therefore, the American troops thought that they had encountered a group of Chinese. However, the Japanese soon began to deploy and take cover and opened fire on the American troops. The Americans did not disperse properly since they were on a very narrow ridge, and a fire fight developed. Four American casualties were sustained, and numerous casualties were inflicted on the enemy.

Case 116.—Severe penetrating wound of the occipital region of the head and a bayonet wound of the neck. The latter wound was probably inflicted after the man was killed by the head wound. This man was attempting to take cover from the enemy when he was struck by a bullet from a Japanese light machinegun at a 75-yard range. Classified as KIA. This casualty might have been avoided if some distinction had been made between Japanese and Chinese uniforms.

Case 117.—Moderately severe lacerating wound of the right side of the head and the right eye. This man was in a prone position firing his M1 rifle when he was struck by a .25 caliber rifle bullet at a 75-yard range. Classified as WIA, second echelon type.

Case 118.—Severe perforating wound of the thorax. This man was in a standing position attempting to put a light machinegun into operation when he was struck by a Japanese light machinegun bullet at a 100-yard range. Classified as KIA. Notwithstanding the fact that this man sustained a perforating wound of the left lung and the heart, he was conscious for approximately 3 minutes before he died.

Case 119.—Moderately severe penetrating wounds of the abdomen. This man was attempting to reach the body of Case 116 when he was struck by an enemy light machinegun bullet. The bullet perforated his canteen before entering his abdomen. Classified as WIA, immediate duty type. This casualty might have been avoided if the battalion commander had been aware of the true tactical situation.

16.—The first platoon of Company L was engaged in setting up a perimeter for the night in the vicinity of a somewhat protected ridge to the left of the trail near the entrance to the village. Two men who had been assigned a sector in back of a small ridge which offered excellent protection became casualties when they carelessly exposed themselves.

Case 120.—Severe perforating wound of the thorax. This man was on defensive action and was standing on a small ridge 70 yards from a Japanese-held village when he was struck by a sniper's bullet. Classified as KIA. This casualty could have been avoided.

Case 121.—Moderately severe laceration of the left buttock. This man was standing near Case 120 and was attempting to assume a prone position when he was struck by an enemy sniper's bullet at a 70-yard range. Classified as WIA, first echelon type. This casualty could have been avoided.

17.—On 13 May 1944, the Khaki Combat Team was sent on a flanking movement to the left of the village in order to form a trail block on a trail leading north from the village. At the same time, two Chinese companies were to form trail blocks on two trails entering from the south. The entire combat team dug in on the sides of the razorback ridge over which the trail led. During the rest of the day, numerous casualties were sustained.

Case 122.—Multiple, severe penetrating wounds of the abdomen and the right lower extremity. This man was on offensive action and was walking up the trail in attempt to locate a Japanese sniper when he was struck by a .25 caliber bullet at a 100-yard range. The bullet hit and exploded a U.S. grenade which was carried in his belt. Classified as DOW, with a 4-hour survival time. This casualty might have been avoided if he had taken advantage of protective cover and concealment.

Case 123.—Mild penetrating wound of the thorax. This man was in a kneeling position administering blood plasma to Case 122 when he was struck by a fragment from a Japanese knee mortar which had a tree burst at a 10-yard range. Classified as WIA, immediate duty type.

Case 124.—Mild penetrating wound of the right thigh. This man was on offensive action and was walking by the aid station when a knee mortar exploded at a 10-yard range. Classified as WIA, immediate duty type.

Case 125.—Mild penetrating wound of the left leg. This man was wounded under circumstances similar to those of Case 124. Classified as WIA, immediate duty type.

Case 126.—Moderately severe perforating wound of the left thigh. This man was a member of a squad which was being moved across a trail which was exposed to enemy fire. While running across the trail, he was hit by a sniper's bullet at a 75-yard range. Classified as WIA, second echelon type. This casualty might have been avoided if he had taken proper precaution in crossing the trail.

Case 127.—Mild laceration of the face. This man, while on offensive action sitting in back of a bank, was preparing to cross the trail when fragments from a sniper's bullet struck him in the face. Classified as WIA, immediate duty type.

Case 128.—Moderately severe penetrating wounds of the occipital region of the head. This man was on defensive action sitting on the edge of the trail when he was struck by fragments from a knee mortar shell which had a tree burst at a 3-yard range. Classified as WIA, first echelon type. This casualty could have been avoided if he had worn his helmet and if he had attempted to take advantage of protective cover.

Case 129.—Moderately severe penetrating wounds of the head and of the thorax. This man was wounded under circumstances similar to those of Case 128. Classified as WIA, first echelon type. This casualty could have been avoided.

Case 130.—Mild penetrating wound of the left leg. This man was wounded under circumstances similar to those of Case 128. Classified as WIA, immediate duty type.

Case 131.—Moderately severe penetrating wound of the right foot. This man was wounded under circumstances similar to those of Case 128. Classified as WIA, second echelon type.

Case 132.—Severe penetrating wound of the head with compound fracture of the skull. This man was on defensive action and was sitting in a rather well protected spot. When he removed his helmet to look over the small ridge which was protecting him, he was struck by a .25 caliber sniper's bullet at a range of approximately 100 yards. He was attended by a surgeon but did not arrive at a main aid station until 14 hours later. Classified as DOW, with a 40-hour survival time. He died while being carried on a litter to the evacuation point. This casualty might have been avoided if he had worn his helmet.

Case 133.—Moderately severe penetrating wound of the right arm. This man was wounded in the same vicinity as Case 132. He was struck by a .25 caliber bullet at a 70-yard range. Classified as WIA, first echelon type.

Case 134.—Severe penetrating wound of the thorax. This man was on offensive action and was advancing in a crouched position when he was struck by the first burst of a Japanese light machinegun at a range of approximately 50 yards. Classified as KIA. This casualty might have been avoided if he had taken advantage of protective cover and of a prone position.

Case 135.—Multiple penetrating and perforating wounds of the right thigh. This man was wounded under circumstances similar to those of Case 134. Classified as WIA, second echelon type. This casualty, which might have been avoided, occurred because the man was attempting to reach Case 134 while the enemy was still firing.

Case 136.—Mild laceration of the left shoulder. This man was on defensive action walking down a trail when he was wounded by an enemy light machinegun bullet at a range of approximately 70 yards. Classified as WIA, immediate duty type. This casualty could have been avoided if he had taken advantage of protective cover.

18.—During the afternoon of 13 May, the Chinese casualties began to filter back to the 42d Portable Surgical Hospital. They left an estimated 5 dead in the jungle and sent out approximately 25 WIA. At least 90 percent of the wounds had been caused by mortar fire. In this group of casualties, no brain or penetrating abdominal wounds were seen. Surgery consisted of simple debridement only.

On 13 May, the Khaki Combat Team was ordered to the right flank, and a Chinese company took over the defense of the main trail for 300 or 400 yards in back of the Orange Combat Team which was working up the trail toward the village. The Chinese troops neglected to make a strong point of the high ground to the left of the trail and put inadequate defense along the small trail which ran over into the main trail. Five Japanese with a light machinegun set up on this ground and commanded the entire main trail. The Chinese were unable to cope with the situation and in attempting to knock out the machinegun one of the American muleskinners was killed and one wounded. Later in the day, a heavy machinegun was brought up from the Orange Combat Team, and the Japanese gun was soon knocked out.

19.—On 14 May 1944, the King Force received orders to break off contact with the enemy and proceed toward Myitkyina. The 1st Battalion, with the 150th Chinese Infantry Regiment, had already proceeded on the way to the airfield. The King Force was disbanded on 24 May. After 18 May, the 3d Battalion had little contact with the enemy, and the men were gradually replaced by the 236th Engineer Combat Battalion. Most of the original unit was evacuated by 1 June, but approximately 150 men remained and fought in various capacities during the next 2 months.

The Orange Combat Team sustained one casualty on the afternoon of 18 May.

Case 137.—Severe penetrating wound of the right thigh. This man was on offensive action in a prone position and was protected by a small ground elevation when he was struck by a .25 caliber rifle bullet at a range of approximately 150 yards. Classified as WIA, second echelon type.

While the 3d Battalion was working its way down the Mogaung-Myitkyina Road toward its junction with the Sumprabum Road, two casualties were sustained during patrol activity.

Case 138.—Severe perforating wound of the abdomen. This man, on patrol activity, had located an enemy automatic weapon emplacement. Instead of taking advantage of protective cover and waiting for the remainder of his patrol to reach him, he continued to advance in a standing position and was struck by a Japanese light machinegun bullet at a range of approximately 100 yards. Despite his wound, he managed to walk 60 yards to an aid station. He was then evacuated by litter 5 miles to Myitkyina where a laparotomy was performed. Classified as WIA, U.S. evacuation type. This casualty might have been avoided if he had used better judgement.

Case 139.—Severe perforating wound of the thorax. This man was on defensive action and at 2300 hours stood up in his foxhole. A guard who was located 5 yards in front of him mistook him for a Japanese and shot him with his M1 rifle. Classified as KIA. This casualty could have been avoided.

On 23 May 1944, while holding a roadblock near Charparte, the Orange Combat Team had several five-man outposts. Case 140 was in an outpost 400 yards from the perimeter and had been informed that the Japanese would be through the area during the day. The outpost was in a well-protected position and was armed with one Browning automatic rifle and four M1 rifles. Case 140 saw a man approaching the outpost and instead of waiting for positive identification went to meet him. The American soldier was mortally wounded before the Japanese soldier was killed.

Case 140.—Severe perforating wounds of the thorax. This man was hit by a .25 caliber rifle bullet at a 50-yard range. This casualty was carried 400 yards to an aid station where he was given plasma. No litter planes were available so the man could not be evacuated.

He died 14 hours later. Classified as DOW, with a 14-hour survival time. This casualty could have been avoided.

During the night of 23 May, the 3d Battalion continued to hold the Mogaung-Myitkyina Road as it passed through the village of Charparte. It was the feeling of the majority of the officers that the perimeter was too large and that the defensive plan was poor. The Charparte region was quite flat and most of the area occupied open terrain. Early in the evening, 20 Chinese had passed a 5-man American outpost 400 yards west of the perimeter and had continued through the U.S. lines. The night was very dark and it was raining and at 2300 hours a company of Japanese passed by the outpost before the Americans realized what was happening. The outpost did not have any communication with the perimeter, and the men left the outpost and started back toward the perimeter by way of the jungle. The Japanese were first to reach the perimeter, and since they were mistaken for Chinese approximately 30 enemy troops entered the area before they were challenged. The remainder of the enemy deployed about the area. During the fight which followed, the 3d Battalion sustained five KIA and five WIA casualties. It was estimated that the Japanese had approximately 50 casualties with 15 dead. Hand grenade fragments killed two Americans and wounded two others. One man had a bayonet wound, and the rest of the casualties were due to small arms fire.

Case 141.—Multiple penetrating and perforating wounds of the anterior surface of the thorax and abdomen. In addition, there were numerous bayonet wounds inflicted after death. This man was a member of the outpost attempting to reach the perimeter when he ran into the midst of a group of Japanese. An enemy hand grenade exploded a few inches from the center of his chest. Classified as KIA.

Case 142.—This man was killed under circumstances similar to those of Case 141.

Case 143.—Multiple penetrating wounds of the head and thorax. This man was on defensive action in a prone position in a foxhole when he was struck by fragments from an enemy hand grenade. Classified as WIA, first echelon type.

Case 144.—Multiple penetrating wounds of the thorax. This man was wounded under circumstances similar to those of Case 143. Classified as WIA, second echelon type.

Case 145.—Severe penetrating wound of the right forearm and a compound comminuted fracture of the radius. This man was in defensive action in a prone position in a foxhole when he was struck by an enemy rifle bullet at a 10-yard range. Classified as WIA, second echelon type.

Case 146.—Multiple penetrating wounds of the thorax, the right upper extremity, and the left buttock. This man was on defensive action and was a member of a machinegun section which had become disorganized. In attempting to find the company command post, he walked into the center of a group of Japanese. He did not have any weapon and was bayoneted by the enemy. Classified as WIA, second echelon type. This casualty could have been avoided.

Case 147.—Severe perforating wound of the neck. This man, on defensive action in a prone position under a shelter half, became excited and attempted to crawl away. He was shot by another American with an M1 rifle. Classified as KIA. This casualty could have been avoided. This man's companion continued to stay under the shelter and killed several Japanese with his pistol.

Case 148.—Severe perforating wound of the left side of the thorax. This man, while on defensive action, had taken cover under a shelter half without the protection of a foxhole. He left the shelter half and was in a standing position calling over the radio when he was struck by an enemy rifle bullet at a close range. Classified as KIA. This casualty could have been avoided.

Case 149.—Severe perforating wound of the thorax. This man was in a prone position in a foxhole but assumed a kneeling position in order to use the telephone. He was killed instantly by an enemy rifle bullet at a 20-yard range. This casualty could have been avoided.

Case 150.—Moderately severe penetrating wound of the abdomen. This man had left the protection of his foxhole in an attempt to aid Case 148. He was struck by an enemy rifle bullet at a 25-yard range. Classified as WIA, second echelon type. This casualty could have been avoided.

On 24 May, the 3d Battalion formed a perimeter across the Myitkyina railroad. Numerous night skirmishes took place with the Japanese. Two days later, a 10-man American patrol, armed with 4 Browning automatic rifles, 1 Thompson submachinegun, and 5 M1 rifles encountered 45 Japanese armed with 4 light machineguns and 1 knee mortar. Twenty Japanese were killed and a large number were wounded. There were no American casualties.

On 26 May, Case 151 was told to lead a patrol to the east beyond the advance outpost. He was aware that Japanese troops were in the area but advanced alone to the designated spot and was wounded by an enemy hand grenade.

Case 151.—Multiple penetrating wounds of the face, thorax, and abdomen. All the wounds seemed to involve soft tissue only. This man had advanced 100 yards from the outpost when he was struck by fragments from a Japanese hand grenade which exploded a few feet in front of him. Classified as WIA, second echelon type. This casualty might have been avoided if he had taken advantage of protective cover. In addition, it was felt that this was an unnecessary patrol.

In the period from 18 to 26 May, there were approximately 541 American troops and 276 Japanese troops involved in the fighting. The Americans sustained a total of 15 casualties (5 KIA, 1 DOW, and 9 WIA). The Japanese sustained approximately 83 casualties.

APPENDIX D

Principal and Associated Wounds

A summary of the battle casualty deaths listed as to the site of the principal wound has already been presented in Chapter VII (p. 499). Considerable more information is available for each case relating to the region of the principal wound and the presence of associated wounds in other body regions. These detailed data are presented in tables 1 and 2.

TABLE 1.—*Distribution of associated wounds as related to the region of the principal wound in Fifth U.S. Army hospital battle casualty deaths*

Region of associated wound	Abd (408)	Cran (297)	ThAbd (212)	Thor (138)	LE,B (114)	UnMW (114)	CoA&T (59)	LE,S (31)	Spin (27)	Cerv (25)	UE,B (10)	MaxF (8)	UE,S (4)	AbdW (3)	Total (1,450)
Head:															
Eye or orbit		22				3									25
Intracranial:															
Known	2		6	2		39	7	1	2	1					60
Suspected	6		2	6	3	10	2				1	4	1		35
Scalp only	7		2	5	5	1	3	2		1		1			27
Face and jaws:															
Bone and soft tissue	4	35	3	5	1	13	1		1	2					65
Eye or orbit	2	11	2	4	3	12	5				1	5			45
Soft tissue only	15	25	3	14	10	27	9	3	1	4	2		1		114
Neck:															
General (excluding spinal)	9	17	12	14	4	23		1	21			3			104
With carotid artery involved				1		1									2
With larynx or trachea involved		2	1			2	2		1	1					9
Spinal cord or intravertebral nerves	26	2	19	22		10	5	1							85
Chest:															
Chest wall only	41	11			8	15	1	1	4	1	1	1	1	1	86
Combined intra-abdominal and intrathoracic		2			1	4				1					8
Intrathoracic, known	6	24	14		2	32	1		7	8					94
Thoracoabdominal	1	1		1		2									5
Abdomen:															
Abdominal wall only		11		8	15	19		6	1		3		1		64
Combined intra-abdominal and intrathoracic		1			1										2
Intra-abdominal:															
Known		5		1	2	12									20
Suspected				4	2	22						1	1		30
Thoracoabdominal						2									2
Upper extremity:															
Soft tissue only	63	52	29	28	17	32	14	6	6	4		3		2	256
Soft tissue and artery	2	1	1	1											5
Soft tissue and artery and bone	3	1		1		2	4								11
Soft tissue and artery and bone and nerve										1					1
Soft tissue and artery and nerve		1	1												2
Soft tissue and bone	34	24	31	33	18	27	11	3	4	4					189
Soft tissue and bone and nerve	1	1	1	1	2	1	1								8
Soft tissue and nerve	1		1	1											3
Traumatic amputation		1	2		2	10	1	1							17

See footnotes at end of table.

TABLE 1.—*Distribution of associated wounds as related to the region of the principal wound in Fifth U.S. Army hospital battle casualty deaths*—Continued

Region of associated wound	Abd (408)	Cran (297)	ThAbd (212)	Thor (138)	LE,B (114)	UnMW (114)	CoA&T (59)	LE,S (31)	Spin (27)	Cerv (25)	UE,B (10)	MaxF (8)	UE,S (4)	AbdW (3)	Total (1,450)
Lower extremity:															
Soft tissue only	135	37	43	26		39	25		3	3	2	1	1	1	316
Soft tissue and artery	6	1			1	3	1								12
Soft tissue and artery and bone	2	2	3	3		3									13
Soft tissue and artery and bone and nerve						1	1								2
Soft tissue and artery and nerve															
Soft tissue and bone	55	21	13	11	1	28	9	3			3		1		145
Soft tissue and bone and nerve	3				2	1									6
Soft tissue and nerve	2					2		1							5
Traumatic amputation	5	1	1		2	10	2	1							22
Arteries injured (excluding traumatic amputations):															
Axillary	1			1								1	1		4
Brachial	4	3	2	1		1	2								13
Femoral	7	1		1	6	4		9							28
Intra-abdominal	25	1	4			1									32
Intracranial [1]		28				2									30
Intrathoracic			1	7		1									9
Multiple	1	2	1		1										5
Others								1		3					4
Popliteal				1		5	2								8
Radial or ulnar						1	2				1				4
Subclavian										3					3
Tibial or peroneal	1	1	2	2	8	1	2	3							20
Nerves injured (excluding traumatic amputations):															
Brachial plexus				2		1			2	3					8
Femoral								2							2
Median	1		1		1					1					4
Multiple					2	1	1			2					6
Other nerve [2]	1					1				2					4
Other plexus	1		1												2
Peroneal					1		1								2
Radial	2	1					2			1	1				7
Sciatic	6				1	1	2								10
Tibial			1		2	1	1	1							6
Ulnar		1	1	1	3	1					1				8
Unclassified													1		1

[1] Artery or venous sinus.

[2] Extracranial or extraspinal.

NOTE.—Key for abbreviation.

Abd (intra-abdominal)
Cran (intracranial)
ThAbd (thoracoabdominal)
Thor (intrathoracic)
LE,B (lower extremity, with bone involvement)
UnMW (unclassified, multiple wounds)
CoA&T (combined intra-abdominal and intrathoracic)
LE,S (lower extremity, soft tissue only)
Spin (intravertebral)
Cerv (cervical)
UE,B (upper extremity, with bone involvement)
MaxF (maxillofacial, with bone involvement)
UE,S (upper extremity, soft tissue only)
AbdW (abdominal wall)

Figures in parentheses are number of cases in each group.

TABLE 2.—*Regional distribution of principal and associated wounds, showing the number of cases exhibiting each [1] in Fifth U.S. Army hospital battle casualty deaths*

Region of associated wound	Principal wound	Associated wounds evident [2]	Total
Head:			
Eye or orbit	----------	25	25
Intracranial, known	297	60	357
Scalp (without known intracranial wound)	----------	27	27
Total	297	112	409
Face and jaws:			
Bone and soft tissue	8	65	73
Eye or orbit	----------	45	45
Soft tissue only	----------	114	114
Total	8	224	232
Neck:			
General (excluding spinal)	12	104	116
With carotid artery involved	7	2	9
With larynx or trachea involved	6	9	15
Total	25	115	140
Spinal cord or intravertebral nerves	27	85	112
Chest:			
Chest wall only	----------	86	86
Combined intra-abdominal and intrathoracic	18	8	26
Intrathoracic, known	138	94	232
Thoracoabdominal	121	5	126
Total	277	193	470
Abdomen:			
Abdominal wall only	3	64	67
Combined intra-abdominal and intrathoracic	41	2	43
Intra-abdominal, known	408	20	428
Thoracoabdominal	91	2	93
Total	543	88	631
Upper extremity:			
Soft tissue only	3	256	259
Soft tissue and artery	----------	5	5
Soft tissue and artery and bone	----------	11	11
Soft tissue and artery and bone and nerve	1	1	2
Soft tissue and artery and nerve	1	2	3
Soft tissue and bone	6	189	195
Soft tissue and bone and nerve	1	8	9
Soft tissue and nerve	----------	3	3
Traumatic amputation	2	17	19
Total	14	492	506

See footnotes at end of table.

TABLE 2.—*Regional distribution of principal and associated wounds, showing the number of cases exhibiting each* [1] *in Fifth U.S. Army hospital battle casualty deaths*—Continued

Region of associated wound	Principal wound	Associated wounds evident [2]	Total
Lower extremity:			
Soft tissue only	17	316	333
Soft tissue and artery	12	12	24
Soft tissue and artery and bone	14	13	27
Soft tissue and artery and bone and nerve	3	2	5
Soft tissue and artery and nerve	1	----------	1
Soft tissue and bone	53	145	198
Soft tissue and bone and nerve	1	6	7
Soft tissue and nerve	1	5	6
Traumatic amputation	43	22	65
Total	145	521	666
Arteries injured (excluding those in traumatic amputations):			
Axillary	----------	4	4
Brachial	----------	13	13
Femoral	----------	28	28
Intra-abdominal	----------	32	32
Intracranial (artery or venous sinus)	----------	30	30
Intrathoracic	----------	9	9
Multiple	----------	[1] 5	[1] 5
Others	----------	4	4
Popliteal	----------	8	8
Radial or ulnar	----------	4	4
Subclavian	----------	3	3
Tibial or peroneal	----------	20	20
Total	----------	155	155
Nerves injured (excluding those in traumatic amputations):			
Brachial plexus	----------	8	8
Femoral	----------	2	2
Median	----------	4	4
Multiple	----------	[1] 6	[1] 6
Other nerve (extracranial or extraspinal)	----------	4	4
Other plexus	----------	2	2
Peroneal	----------	2	2
Radial	----------	7	7
Sciatic	----------	10	10
Tibial	----------	6	6
Ulnar	----------	8	8
Unclassified	----------	1	1
Total	----------	54	54
Unclassified (as to principal wound):			
Multiple wounds (included among associated wounds listed)	114	----------	114
Grand total	1,450	2,039	3,489

[1] Not the total number of wounds present.

[2] A total of 126 associated wounds were suspected as follows: Intracranial, 35; intrathoracic, 61, and intra-abdominal, 30.

APPENDIX E

Combined Wound Groups

A detailed classification of three of the wound classes (intrathoracic, thoracoabdominal, and combined intra-abdominal and intrathoracic wounds) with emphasis upon the relative importance of abdominal and thoracic components when both are present is presented in table 1. A summarized listing of this information has already been presented in chapter VII (p. 502).

TABLE 1.—*Classification of cases with principal wounds of chest to show hemothorax and relative importance of abdominal and thoracic components when both are present*

[Data are based on severity of internal injury and surgical approach]

Abdominal and thoracic components	Abdomen	Chest	Total
Combined intra-abdominal and intrathoracic:			
Bilateral	10	6	16
Left	15	4	19
Right	16	8	24
Total	41	18	59
Intrathoracic:			
Bilateral	----------	26	26
Left	----------	43	43
Right	----------	65	65
Unclassified	----------	4	4
Total	----------	138	138
Thoracoabdominal:			
Bilateral	3	4	7
Left	41	67	108
Right	45	50	95
Unclassified	2	----------	2
Total	91	121	212
Grand total	132	277	409

NOTE.—Data from study of Fifth U.S. Army hospital battle casualty deaths.

APPENDIX F

Detailed Observations on Wound Groups

The tables (1 through 15) in this section are largely self-explanatory.[1] Primary operations, subsidiary operations, operating time, secondary operations, and anesthesia for primary surgery are presented in the order named (tables 1, 2, 3, 4, and 5). The recorded information relative to oxygen therapy is presented in table 6. There was no record of oxygen therapy in 886 of the 1,450 deaths. It is most probable that oxygen was given at times without making an entry on the patient's record. It is known, however, that oxygen therapy was indicated at times when it was not given. The cases listed in the column devoted to oxygen therapy during operation are, with few exceptions, those to which oxygen was administered as a part of the anesthetic mixture.

Chemotherapy, plasma and blood therapy, recorded blood pressure, evidence of shock, urinary output, and other miscellaneous observations as related to the principal wound are shown in tables 7 through 13.

Table 14 shows that 945 of the deaths studied occurred in evacuation hospitals and 505 in field hospitals. In the group of 65 cases that were seen in a field hospital and transferred to an evacuation hospital for surgery, those with intracranial wounds (32 cases) head the list. The policy of transferring nearly all with intracranial wounds to an evacuation hospital for surgery accounts for this figure, and it is fair to assume that few if any of these would have survived had they been held in the field hospitals. The same is not true of the 10

TABLE 1.—*Primary operations as related to principal wounds*

Principal wound	Amputation	Craniotomy	Debridement only	Laminectomy	Laparotomy	Thoracolaparotomy	Thoracotomy	Abdominal stab incision without laparotomy	Others	Total primary operations
Intracranial	3	101	20	--------	5	--------	--------	--------	2	131
Intravertebral	--------	--------	5	12	--------	--------	--------	--------	--------	17
Maxillofacial	--------	--------	5	--------	--------	--------	--------	--------	2	7
Cervical	--------	1	11	--------	--------	--------	--------	--------	6	18
Intrathoracic	2	1	40	4	2	--------	33	--------	1	83
Thoracoabdominal	5	--------	6	--------	100	12	109	18	--------	250
Combined intra-abdominal and intrathoracic	8	--------	1	1	42	--------	7	--------	1	60
Intra-abdominal	11	--------	5	3	327	1	--------	--------	--------	347
Abdominal wall only	--------	--------	1	--------	2	--------	--------	--------	--------	3
Upper extremity:										
Soft tissue only	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Bone and soft tissue	2	--------	5	--------	--------	--------	--------	--------	--------	7
Lower extremity:										
Soft tissue only	5	--------	16	--------	2	--------	--------	--------	--------	23
Bone and soft tissue	40	--------	36	--------	1	--------	--------	--------	1	78
Unclassified multiple	8	5	25	3	8	1	2	1	2	55
Total	84	108	176	23	489	14	151	19	15	1,079

[1] General observations on wound groups in the 1,450 Fifth U.S. Army hospital battle casualty deaths have been presented in chapter VII (p. 485).

TABLE 2.—*Subsidiary operations performed at the time of the primary operation as related to principal wounds*

Principal wound	Bronchoscopy	Cast or plaster splint	Enucleation	Intercostal nerve block	Ligation of artery	Maxillofacial repair	Orchidectomy	Other operation	Repair of artery	Sympathectomy	Tracheotomy	Vitallium cuff used in artery	Total subsidiary operations
Intracranial	1	12	5	1	10	9					1		39
Intravertebral		5				1		6					12
Maxillofacial			1			4					2		7
Cervical	1	1			8	1		1	1		3	1	17
Intrathoracic	12	12		7	3	5		5			1		45
Thoracoabdominal	18	12	1	5	4	1		8					49
Combined intra-abdominal and intrathoracic	2	8			4			4			1		19
Intra-abdominal	5	43		1	23	5	2	21	1	1	1		103
Abdominal wall only		1						1					2
Upper extremity:													
Soft tissue only													
Bone and soft tissue	1	2			1	1							5
Lower extremity:													
Soft tissue only		8			10								18
Bone and soft tissue		51	1		8	1	1	2	1	1			66
Unclassified multiple	1	16	1		6	3	2	1		1	3		34
Total	41	171	9	14	77	31	5	49	3	3	12	1	416

cases with unclassified multiple wounds and the 8 cases with intrathoracic wounds in this group. Many of these might have survived had they been held for surgery in the field hospital. These two principal wound groups are the ones in which the transportability of the battle casualty is apt to be overestimated.

Table 15 on post mortem examinations shows that there were 675 cases in which there was no record of autopsy. It is known that a number of autopsies were done that were not reported. However, many more should have been done, and in many instances would have been done, had the pressure of work with living battle casualties not been so great. It was demonstrated time and again that every surgeon should do or witness the post mortem examination on all of his patients that die. His judgment and ability in the problems of war surgery, particularly, develop much more rapidly and to a far greater degree when this is done routinely. Microscopic examinations of tissues from all the important organs is likewise most valuable. Excellent reports from the 2d Medical Laboratory and the 15th General Medical Laboratory constitute a part of the record of many of the deaths studied. The high incidence of fat embolism was not appreciated until Colonel Mallory advised of its incidence in the microscopic sections of tissues from battle casualty deaths. Microscopic examination of tissues in those dying with pigment nephropathies has been quite valuable. Gross and microscopic autopsy studies should be required on all battle casualty deaths. Their educational byproducts contribute to the effectiveness of an army.

TABLE 3.—*Operating time (in minutes) for primary surgery as related to principal wounds*

Principal wound	Less than 30	30–59	60–89	90–119	120–149	150–179	180–209	210–239	240–299	300–360	More than 360	No record
Intracranial	2	3	8	7	8	5	5		1	1	2	87
Intravertebral	1				2							15
Maxillofacial					1	1	1					4
Cervical	1			1	1				2			13
Intrathoracic		4	2	2	4	3		1		1	1	63
Thoracoabdominal	1	2	8	6	11	8	5	4	3	5	1	131
Combined intra-abdominal and intrathoracic			1		1	2	4	1	1	1		36
Intra-abdominal	4	4	6	9	16	17	19	8	6	1		247
Abdominal wall only												3
Upper extremity:												
Soft tissue only												
Bone and soft tissue				1								6
Lower extremity:												
Soft tissue only		1		3								18
Bone and soft tissue		4	6	3	2	2	2					59
Unclassified multiple	2	1	2	4	2	3	1			2		35
Total	11	19	33	36	48	41	37	14	13	11	4	717

TABLE 4.—*Secondary (later) operations as related to principal wounds*

Principal wound	Abdominal stab incision without laparotomy	Amputation	Bronchoscopy	Cast or plaster splint	Craniotomy	Cystostomy	Debridement	Died during secondary surgery	Drainage tube to pleural sac inserted	Dressing [1]	Fasciotomy	Incision of abscess	Laminectomy	Laparotomy	Opening of colostomy [1]	Other operations	Renal decapsulation	Secondary closure	Third or more operations	Thoracotomy	Total secondary operations
Intracranial		1	2	2	16		7	1	1			2		1		3		1	6		43
Intravertebral			1	1		2	1														5
Maxillofacial																					
Cervical							1	1								1					3
Intrathoracic		1	1	3	1	1	2		4				1							1	15
Thoracoabdominal	1	1	3		1		5		5			1		3				2	4	1	27
Combined intra-abdominal and intrathoracic									1					1			1				3
Intra-abdominal		4	2			3	7							5	2	4	1	5	3		36
Abdominal wall only																					
Upper extremity:																					
Soft tissue only																					
Bone and soft tissue							1			1											2
Lower extremity:																					
Soft tissue only		2					3			1	1										7
Bone and soft tissue		6				1	3			3				2					1		16
Unclassified multiple					3		2	2				1		1							9
Total	1	15	9	6	21	7	32	4	11	5	1	4	1	13	2	8	2	8	14	2	166

[1] Recorded only when done under anesthesia.

TABLE 5.—*Anesthesia for primary surgery as related to principal wounds*

Principal wound	Ether, closed system	Ether, Flagg method	Ether, open drop	Ether, unclassified	Endotracheal	Nitrous oxide	Local	No record or none	Other agent[1]	Thiopental sodium	Regional	Spinal
Intracranial	16	1	5	24	31	8	42	31		33	1	
Intravertebral	2			5	4	2	5	5				
Maxillofacial	2		1		2	2	1	3		1		
Cervical	6		1		2	5	3	7		3		
Intrathoracic	31		1	20	33	22	9	18	1	11		
Thoracoabdominal	89	1	5	55	100	77	3	35		3		
Combined intra-abdominal and intrathoracic	23		1	19	22	20	1	4	1	3		
Intra-abdominal	119	2	25	107	112	96		96	1	8		
Abdominal wall only				2	1			1		1		1
Upper extremity:												
Soft tissue only												
Bone and soft tissue	1			1	2	1		2		3		
Lower extremity:												
Soft tissue only	4		5	4		4		3		7		1
Bone and soft tissue	20		1	18	6	16		23		9		1
Unclassified multiple	11			22	16	9	3	14		8		
Total	324	4	45	277	331	232	67	242	3	90	1	3

[1] Including ethyl chloride used for induction.

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TABLE 6.—*Oxygen therapy as related to principal wound*

Principal wound	Oxygen before operation	Oxygen during operation	Oxygen after operation	No record of oxygen
Intracranial	25	21	20	240
Intravertebral	4	2	3	18
Maxillofacial		2		6
Cervical	8	8	2	13
Intrathoracic	22	35	24	74
Thoracoabdominal	18	99	39	90
Combined intra-abdominal and intrathoracic	12	24	9	24
Intra-abdominal	26	131	63	227
Abdominal wall only		1	1	1
Upper extremity:				
Soft tissue only	1			3
Bone and soft tissue		1	1	9
Lower extremity:				
Soft tissue only	1	5	7	21
Bone and soft tissue	6	21	21	72
Unclassified multiple	13	13	4	88
Total	136	363	194	886

TABLE 7.—*Chemotherapy (bacteriostatic drugs [1] and soda) as related to principal wound*

Principal wound	Penicillin alone	Sulfonamide alone	Penicillin and sulfonamide	Soda [2] given	No soda reported	No record of chemotherapy
Intracranial	50	37	23	17	48	187
Intravertebral	8	4	4	2	8	11
Maxillofacial	2	1			1	5
Cervical	5	3	1		4	16
Intrathoracic	12	21	19	3	38	86
Thoracoabdominal	37	58	30	7	85	87
Combined intra-abdominal intrathoracic	13	15	5	4	19	26
Intra-abdominal	47	127	71	10	191	163
Abdominal wall only		1			1	2
Upper extremity:						
Soft tissue only	1			1		3
Bone and soft tissue	1	5		1	4	4
Lower extremity:						
Soft tissue only	4	13	3	4	14	11
Bone and soft tissue	12	35	14	7	45	53
Unclassified multiple	13	15	9	3	23	77
Total	205	335	179	59	481	731

[1] Excluding sulfanilamide applied to wounds at time of first aid dressing.
[2] Including 26 cases in which soda was given without a sulfonamide as an adjuvant to blood transfusion therapy.

TABLE 8.—*Intravenous plasma therapy as related to principal wound*

Principal wound	Units of plasma (one unit is 250 cc.)											
	[1] 0	1	2	3	4	5	6	7	8	9	10	11 or more
	Before admission to hospital											
Intracranial	161	55	40	19	14	2	3	2	1	------	------	------
Intravertebral	10	7	4	4	1	------	------	------	------	1	------	------
Maxillofacial	5	1	2	------	------	------	------	------	------	------	------	------
Cervical	13	3	4	2	1	1	------	------	1	------	------	------
Intrathoracic	57	12	34	13	9	3	6	3	------	1	------	------
Thoracoabdominal	65	32	40	34	25	8	3	2	2	1	------	------
Combined intra-abdominal and intra-thoracic	19	11	10	8	5	3	2	------	------	------	------	[2] 1
Intra-abdominal	148	43	96	40	34	21	15	5	3	1	1	[3] 1
Abdominal wall only	3	------	------	------	------	------	------	------	------	------	------	------
Upper extremity:												
Soft tissue only	4	------	------	------	------	------	------	------	------	------	------	------
Bone and soft tissue	4	1	------	1	1	2	------	------	------	------	------	[4] 1
Lower extremity:												
Soft tissue only	18	2	5	3	1	------	1	------	1	------	------	------
Bone and soft tissue	36	13	21	16	12	4	4	4	2	1	1	------
Unclassified, multiple	57	19	15	14	3	2	1	------	3	------	------	------
Total cases	600	199	271	154	106	46	35	16	13	5	2	3
	After admission to hospital, before surgery											
Intracranial	185	24	43	15	11	8	5	1	1	1	1	[5] 2
Intravertebral	11	3	8	------	1	1	2	------	------	------	------	[6] 1
Maxillofacial	5	------	1	1	------	------	------	1	------	------	------	------
Cervical	20	3	------	2	------	------	------	------	------	------	------	------
Intrathoracic	83	13	16	13	7	4	------	1	------	------	1	------
Thoracoabdominal	138	23	26	13	3	4	1	------	1	1	1	------
Combined intra-abdominal and intra-thoracic	34	6	8	3	4	1	3	------	------	------	------	------
Intra-abdominal	248	27	61	33	20	5	6	2	2	2	------	[7] 2
Abdominal wall only	2	------	------	1	------	------	------	------	------	------	------	------
Upper extremity:												
Soft tissue only	2	1	------	------	------	------	------	1	------	------	------	------
Bone and soft tissue	7	1	------	------	------	------	1	------	------	1	------	------
Lower extremity:												
Soft tissue only	20	4	3	1	3	------	------	------	------	------	------	------
Bone and soft tissue	58	14	11	6	6	6	4	2	3	1	1	[8] 2
Unclassified, multiple	58	15	18	5	4	5	4	------	1	------	1	[9] 4
Total cases	871	134	195	93	59	34	26	8	8	6	5	11

See footnotes at end of table.

TABLE 8.—*Intravenous plasma therapy as related to principal wound*—Continued

Principal wound	Units of plasma (one unit is 250 cc.)											
	[1] 0	1	2	3	4	5	6	7	8	9	10	11 or more
	During surgery											
Intracranial	280	8	6	1	1	1						
Intravertebral	26			1								
Maxillofacial	8	1										
Cervical	22		1		1		1					
Intrathoracic	133	3	1		1							
Thoracoabdominal	193	4	10		1	1	1	1	1			
Combined intra-abdominal and intrathoracic	48	4	2	2		1	1				1	
Intra-abdominal	356	8	19	10	6	2	1		2	1	1	1
Abdominal wall only	3											
Upper extremity:												
Soft tissue only	4											
Bone and soft tissue	10											
Lower extremity:												
Soft tissue only	22	2	1	2	4							
Bone and soft tissue	96	3	12	2	1					1		
Unclassified, multiple	108	4	2									1
Total cases	1,309	37	54	16	15	5	4	1	3	2	2	2
	After surgery											
Intracranial	275	7	6		1		2	1	3	1		
Intravertebral	25	1	1									
Maxillofacial	7		1									
Cervical	23	2										
Intrathoracic	127	3	6		1				1			
Thoracoabdominal	183	11	7	2	3	1	3		1		1	
Combined intra-abdominal and intrathoracic	46	3	4	2	1		2	1				
Intra-abdominal	331	16	24	12	12	4	6					[3] 1
Abdominal wall only	2			1								
Upper extremity:												
Soft tissue only	4											
Bone and soft tissue	9		1									
Lower extremity:												
Soft tissue only	23	5	2				1					
Bone and soft tissue	93	2	7	4	3	1	1	1	1	1		
Unclassified, multiple	103	3	6		1			1	1		2	
Total cases	1,251	53	65	21	22	6	15	4	7	2	3	1

[1] No record of plasma administration, or none given.
[2] 12 units.
[3] 14 units.
[4] 11 units.
[5] 11 units, 17 units.
[6] 18 units.
[7] 13 units.
[8] 12 units, 17 units.
[9] 13 units, 14 units, 29 units (given over period of 4 days—abdominal wound, severed popliteal artery, multiple fractures, and clostridial myositis).

TABLE 9.—*Blood transfusion therapy as related to principal wound*

Principal wound	Units of blood (one unit is 500 cc.)											
	[1] 0	1	2	3	4	5	6	7	8	9	10	11 or more
	Before surgery											
Intracranial	211	37	27	9	6	2	3	1	1			
Intravertebral	14	4	5	2	1	1						
Maxillofacial	5	1	1	1								
Cervical	12	4	3	4	1						1	
Intrathoracic	66	29	18	8	9	6	1		1			
Thoracoabdominal	78	33	39	23	18	6	8	3	1	3		
Combined intra-abdominal and intra-thoracic	25	9	9	6	5	1	2			1	1	
Intra-abdominal	165	56	65	45	41	14	11	5	2	1	3	
Abdominal wall only	2	1										
Upper extremity:												
Soft tissue only	3			1								
Bone and soft tissue	7	1	1		1							
Lower extremity:												
Soft tissue only	22	1	2	3	2	1						
Bone and soft tissue	53	16	16	7	10	7	2	2	1			
Unclassified, multiple	44	27	15	12	9	3	2		1			1
Total cases	707	219	201	121	103	41	29	11	7	5	5	1
	During surgery											
Intracranial	243	20	21	8	2		2		1			
Intravertebral	21	2	1	2		1						
Maxillofacial	8											
Cervical	21	1	2						1			
Intrathoracic	117	9	7	1	3		1					
Thoracoabdominal	132	15	34	16	5	3	6		1			
Combined intra-abdominal and intra-thoracic	34	8	6	5	2	2	1	1				
Intra-abdominal	257	30	53	29	18	6	5	3	1	4	1	1
Abdominal wall only	3											
Upper extremity:												
Soft tissue only	4											
Bone and soft tissue	10											
Lower extremity:												
Soft tissue only	19	4	3	4	1							
Bone and soft tissue	72	6	22	6	1	2	3	1			1	
Unclassified, multiple	96	8	5		1	2		2				
Total cases	1,037	103	154	71	33	16	18	7	4	4	2	1

See footnotes at end of table.

TABLE 9.—*Blood transfusion therapy as related to principal wound*—Continued

Principal wound	Units of blood (one unit is 500 cc.)											
	[1] 0	1	2	3	4	5	6	7	8	9	10	11 or more
	After surgery											
Intracranial	267	11	10	2	4	1	1		1			
Intravertebral	23	2	2									
Maxillofacial	6	1	1									
Cervical	20	4		1								
Intrathoracic	112	13	5	4	3	1						
Thoracoabdominal	159	26	14	2	2	4	1		2	2		
Combined intra-abdominal and intra-thoracic	43	5	7	1	3							
Intra-abdominal	287	48	30	13	10	9	4	1	2	2	1	[2] 1
Abdominal wall only	3											
Upper extremity:												
Soft tissue only	4											
Bone and soft tissue	9		1									
Lower extremity:												
Soft tissue only	23	3	2		3							
Bone and soft tissue	80	11	4	5	3	5	2	2	1		1	
Unclassified, multiple	93	16	7	2	2							
Total cases	1,129	134	83	30	30	20	8	3	6	4	2	1

[1] No record of intravenous administration of blood, or none given.

[2] 12 units.

TABLE 10.—*Lowest recorded systolic blood pressure* [1] *for cases in shock as related to principal wound*

Principal wound	Arterial tension in mm. Hg					
	Zero	2–38	40–58	60–78	80–88	90–98
Intracranial	16		5	18	10	10
Intravertebral	3		3	1	2	5
Maxillofacial			1			
Cervical	4		2		1	3
Intrathoracic	13		2	7	10	9
Thoracoabdominal	18	1	10	23	12	5
Combined intra-abdominal and intrathoracic	11		5	4	6	1
Intra-abdominal	58	3	19	21	18	16
Abdominal wall only						
Upper extremity:						
Soft tissue only	2		1			
Bone and soft tissue	3					
Lower extremity:						
Soft tissue only	3	1		2	1	1
Bone and soft tissue	14	1	4	12	3	3
Unclassified, multiple	13		5	9	6	5
Total cases	158	6	57	97	69	58

[1] Excluding a gradual terminal decline immediately preceding death.

TABLE 11.—*Nature of evidence for shock in cases without recorded hypotension as related to principal wound*

Principal wound	Blood pressure 100 or more, but pulse rapid and weak [1]	Blood pressure 100 or more, but shock recorded	Presence of shock recorded	Shock suspected by inference	Therapy suggests shock	No evidence of shock
Intracranial	10		30	13	63	122
Intravertebral			3		4	6
Maxillofacial				1	4	2
Cervical	1		3	1	5	5
Intrathoracic	3		23	24	40	7
Thoracoabdominal	5		44	17	72	5
Combined intra-abdominal and intrathoracic			10	1	19	2
Intra-abdominal	8	2	93	45	119	6
Abdominal wall only						3
Upper extremity:						
Soft tissue only				1		
Bone and soft tissue					4	3
Lower extremity:						
Soft tissue only			10	3	4	6
Bone and soft tissue	1		26	11	34	5
Unclassified, multiple	1		31	17	20	7
Total	29	2	273	134	388	179

[1] No comment on shock in the case reports.

TABLE 12.—*Urinary output as related to principal wound*

Principal wound	Output adequate	Apparently adequate but record incomplete	Anuria [1]	Oliguria [2] recorded	Oliguria suspected	No record
Intracranial	3	9	2	3	2	278
Intravertebral		3		1	2	21
Maxillofacial						8
Cervical	2	1		1		21
Intrathoracic	5	2	1	2		128
Thoracoabdominal	7	6	5	14	7	173
Combined intra-abdominal and intrathoracic	2			7		50
Intra-abdominal	12	7	13	32	11	333
Abdominal wall only						3
Upper extremity:						
Soft tissue only				1		3
Bone and soft tissue	1					9
Lower extremity:						
Soft tissue only	1	1	1	3	1	24
Bone and soft tissue	3	3		9		99
Unclassified, multiple	1	1		4	2	106
Total cases	37	33	22	77	25	1,256

[1] Less than 100 cc. per diem.
[2] 100 to 800 cc. per diem.

TABLE 13.—*Miscellaneous observations as related to principal wound*

Principal wound	Burns present	Coma on admission	Exposure, severe, before admission	Hemorrhage, profuse, after admission	Peritoneal closure impossible	Tourniquet used before admission
Intracranial	4	167	4	15		1
Intravertebral		1				
Maxillofacial	1	1				
Cervical		4		5		1
Intrathoracic	3	9	1			1
Thoracoabdominal	1	2		3	4	1
Combined intra-abdominal and intrathoracic		3		1	1	1
Intra-abdominal	3	8	2	29	3	7
Abdominal wall only						
Upper extremity:						
Soft tissue only		1				
Bone and soft tissue		1				3
Lower extremity:						
Soft tissue only	1	1	1	1		3
Bone and soft tissue	4	4	1	3		19
Unclassified, multiple	11	16	1	1		5
Total cases	28	218	10	58	8	42

TABLE 14.—*Data relative to distribution of deaths in field and evacuation hospitals*

Principal wound	Field hospital	Evacuation hospital [1]	Transfer [2]	Transfer [3]
Intracranial	25	272	4	32
Intravertebral	2	25		5
Maxillofacial		8		1
Cervical	9	16		1
Intrathoracic	54	84	3	8
Thoracoabdominal	113	99	7	2
Combined intra-abdominal and intrathoracic	29	30	1	
Intra-abdominal	215	193	7	3
Abdominal wall only	1	2	1	
Upper extremity:				
Soft tissue only	1	3		
Bone and soft tissue	2	8	1	1
Lower extremity:				
Soft tissue only	5	26	2	
Bone and soft tissue	32	82	2	2
Unclassified, multiple	17	97	2	10
Total cases	505	945	30	65

[1] Including figures in last two columns.
[2] Primary surgery done in field hospital, and patient died in evacuation hospital after transfer.
[3] Patient seen in field hospital and transferred to evacuation hospital for primary surgery.

TABLE 15.—*Post mortem examinations as related to principal wound*

Principal wound	No autopsy done	Gross reported, but no microscopic	Gross reported, microscopic not reported	Gross and microscopic reported
Intracranial	141	48	10	98
Intravertebral	13	1	1	12
Maxillofacial	2	3	----------	3
Cervical	8	9	1	7
Intrathoracic	69	34	2	33
Thoracoabdominal	79	76	13	44
Combined intra-abdominal and intrathoracic	15	22	1	21
Intra-abdominal	193	130	14	71
Abdominal wall only	2	----------	----------	1
Upper extremity:				
Soft tissue only	3	1	----------	----------
Bone and soft tissue	6	2	----------	2
Lower extremity:				
Soft tissue only	11	5	5	10
Bone and soft tissue	60	20	10	24
Unclassified, multiple	73	14	4	23
Total cases	675	365	61	349

APPENDIX G

Bomb Incident—A Controlled Study

Allan Palmer, M.D.

A bomb, designated as U.S. M41 and described as an antipersonnel fragmentation bomb, exploded when it was dropped accidentally on the concrete surface of dispersal area No. 3 of AAF (Army Air Force) Station 128 at Deenethorpe, England, on 12 June 1944.[1] A mission in which aircraft B-17-G No. 42-107210 was to have taken part was cancelled. The ground crew of the B-17-G ship, together with the ground crew of another ship, were engaged in unloading the clusters of M41 bombs from the bomb racks. A shackle holding three of the bombs to one end of the support for a cluster of six was loose or broken, and during the handing down of the cluster the three bombs fell to the concrete—a distance of approximately 6 feet. One of the bombs exploded, another became armed but did not explode, and the third remained unarmed.

The official ordnance report of the accident by the ordnance officer of the Eighth Air Force is extracted as follows:

1. *Place of accident*: AAF Station 128, 401st Bombardment Group, located near Deenethorpe, England, Grid reference of field 496090.

2. *Time of accident*: 1535 hours, 12 June 1944.

3. *Bombs*: One (1) M41 Fragmentation bomb 20 lb in M1A1 cluster with AN-M110A1, instantaneous fuse.

4. *Condition of bombs*: Bombs were "safe," being unloaded from aircraft on dispersal site #3.

5. *Location of bombs*: On dispersal site #3 near buildings of the 614th Bomber Squadron Technical Supply and derelict farm house.

6. *Effects: A.* Casualties: Seventeen, of which five were killed and four seriously injured.

B. Damage: The bomb bay wing structure and landing gear of a B-17 #107210 were damaged. The aircraft is to be salvaged.

7. *Group and station to which aircraft belonged:* 401st Bomber Squadron Group (H), AAF Station 128.

8. *Events causing accident:* While unloading a cluster of 6 M41 bombs, a clasp holding bombs to carrier (adapter) evidently buckled and broke, releasing three bombs, one of which detonated on striking concrete.

9. *Action:* The loose bombs and clusters were cleared away, dangerous fuse (in one UXB) removed and destroyed. All clusters were removed from aircraft.

10. *Additional remarks: A.* To the best of our knowledge four men of Armament and Ordnance Sections of the 614th Bomber Squadron 401st Bomber Group (H) were working in each side of the bomb bay, two above and two on the ground on each side, with a number of other men standing around or helping in various ways. Usually a crew of four will load or unload a ship, but in this case men who had finished unloading other ships had come over to help finish the job on this one. Both outboard racks had been unloaded and apparently crews had begun work on the double clustered bombs on the inboard racks. It was at this time that the explosion occurred, on the left side of the bomb bay. From the information available, the double clustered bomb on the top station was being removed, although this is not certain. By later comparing lot numbers of bombs and fuses, both loose or partially clustered, it was determined with reasonable certainty from which cluster the exploded bomb came. There were three intact bombs remaining on the rear of this cluster but, the clasp attached to the strip designed to hold the three bombs to the adapter had apparently buckled and had broken, evidently releasing the three bombs which fell to the ground, one of which exploded on impact. The nose portion of the fuse on this bomb was recovered, proving that the fuse was in an unarmed condition. The adapter was of the type used to repair bombs in the U.K. and procured here. There were thus two equipment malfunctions, the broken clasp on the adapter and the AN-M110A1 nose fuse, which functioned, even though in "safe" condition.

B. One bomb from a cluster, other than the one mentioned above, fell and became armed and in a dangerous condition. The striker head and safety collar were missing from the nose of the fuse. The R.A.F. Bomb Disposal Squad at Bramcote was notified, but they stated that they were not permitted by the Air Ministry to dispose of U.S. bombs which had become dangerous during loading or unloading operations, of A/C on the ground. Consequently, the bomb was later safetied by removing and destroying the fuse.

C. The following precautions will be stressed in an effort to prevent any further accidents with this type of bomb: During normal inspection of cluster for damage or indications of possible failure, they will be completely prepared for subsequent loading. The safety pins will be removed from the clasp and replaced with long pieces of arming wire to facili-

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[1] One of the primary reasons for reporting this incident is to illustrate the type of investigation which should follow all accidents involving U.S. weapons. Under these semicontrolled circumstances, exact information can be collected in regard to (1) type of weapon; (2) number of men exposed, posture, duty, equipment and clothing, and distance from weapon; (3) number of casualties, types and severity of wounds, and extent of hospitalization; (4) recovery of fragments or bullets; and (5) documentation with photographs and X-rays. These unfortunate accidents can then be utilized as biological indicators of the effectiveness of our weapons.—J. C. B.

tate removal after loading. Safety wires are required to be in place during loading. The arming wire will be replaced with a 500 lb G.P. bomb arming wire or equivalent, and Farhnestock clips attached.

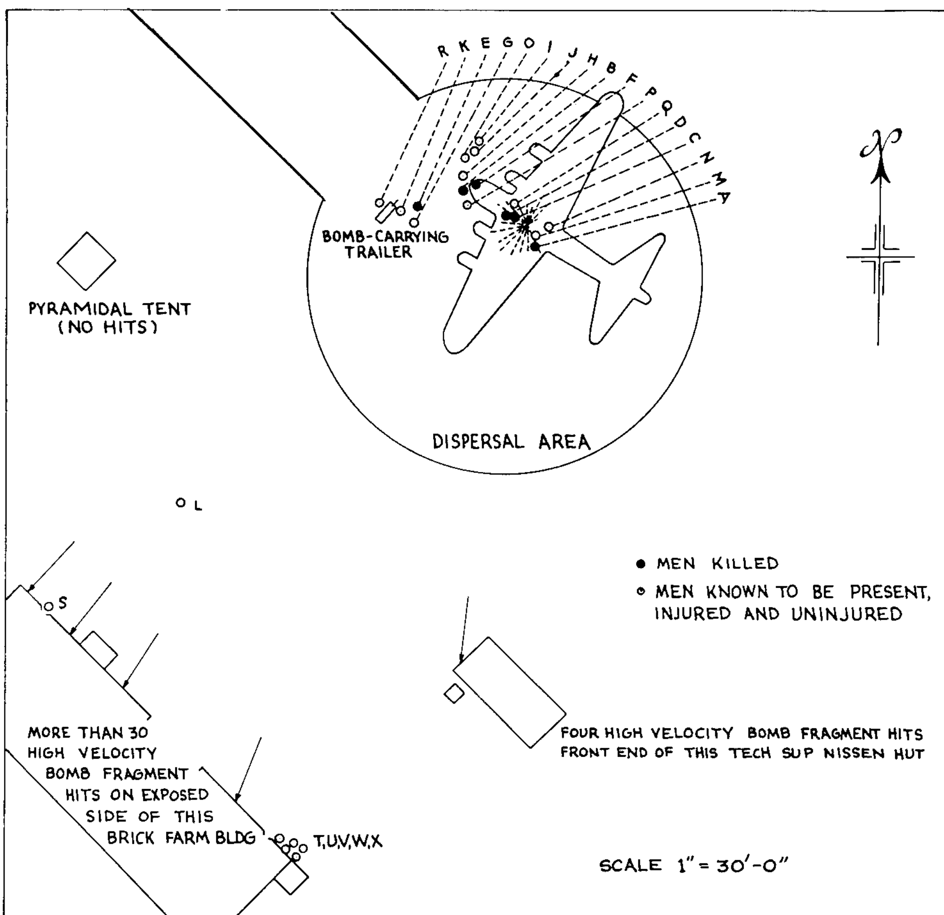
When clusters are to be unloaded, the procedure will be started from the top stations and safety wires inserted in clasps before removing bombs from racks. Although this has been required procedure, the job has been so difficult, because of inaccessibility and lack of time, that it is believed it has not been done consistently. However, this accident is considered attributable primarily to malfunctions resulting from poor equipment designs, rather than the failure to insert the safety wire. The latter procedure will serve more certainly to prevent breaking of clusters by inadvertent removal of the arming wire during handling.

D. All casualties were ground force members of the 614th Bomber Squadron 401st Bomber Group (H).

(Signed) JAMES C. DAVID,
Capt., Ord. Dept.,
Gp. and Sta. Ord. Officer.

SCENE OF THE INCIDENT

Within a 300-foot radius of the point of impact of the bomb that exploded (fig. 1), there were 24 men, 1 aircraft (B–17–G No. 42–107210), 1 pyramidal tent, 1 technical supply nissen hut, 1 brick farm building, and 1 bomb-carrying trailer.



WRAMC-4942-A24

FIGURE 1.—Location of men and buildings within a 300-foot radius of the point of impact of bomb.

Of the 24 men known to be present within a 300-foot radius (table 1), 6 were located just less than the full 300-foot range and were uninjured, although one of these, *S*, standing in the doorway of the brick farmhouse, was struck in the right thigh by a bomb fragment. The missile was reflected against his pocket knife and became buried in the wooden structure of the door. The man furthest from the burst who sustained injury was *L*, approximately 150 feet away. He was walking in the direction of the aircraft and was knocked down by a fragment that struck his left elbow and fractured the medial condyle of his left humerus.

TABLE 1.—*Personnel exposed to explosion of a U.S. 20-pound (M41) fragmentation bomb*

Personnel	Distance from burst	Part of body exposed	Protection	Classification	Disposition
	Feet				
A	21	Front	None	Killed	Buried.
B	25	do	do	do	Do.
C	5	Front (above burst)	do	do	Do.
D	8	Front	do	do	Do.
E	30	Back	do	Died of wounds	Do.
F	23	Front	do	do	Do.
G	31	do	Partial, by left landing gear.	Severely injured	Evacuated to Zone of Interior after 57 days.
H	28	do	Head protected by chin turret.	do	Zone of Interior after 100 days.
I	32	Back	None	do	Returned to duty after 56 days.
J	31	Front	do	do	Returned to duty after 30 days.
K	36	Left side	Partial, by left landing gear.	do	Returned to duty after 42 days.
L	150	Front	None	do	Returned to duty after 23 days.
M	6	Lower limbs (above burst).	do	do	Returned to duty after 29 days.
N	5	Lower limbs (above burst).	Partial, by inboard panel and bomb clusters.	do	Returned to duty after 10 days.
O	29	Front	Partial, by casualty F.	do	Returned to duty after 27 days.
P	23	Front	Partial, by casualty D.	do	Returned to duty after 35 days.
Q	9	Front (above burst)	Complete, by inboard panel and bomb clusters.	do	Returned to duty.
R	40	Front	Bomb trailer	Uninjured	Do.
S	255	do	Pocket knife	do	Do.
T, U, V, W, and X.	300	Unknown	None	do	Do.

The remaining 17 men were within a 40-foot radius and all but one (*R*) were killed or injured. Four men were killed instantly and two died within 24 hours of the time of injury. The other casualties sustained injuries of varying severity. The least serious injury was in a casualty (*Q*) who suffered a very slight tearing of his left eardrum, resulting in a hemorrhage into the auditory canal. He was not sent to hospital but was examined and taken care of at the AAF station. This man was standing forward about 9 feet above the burst in the right bomb bay. He was protected from a direct hit by bomb fragments by the inboard panel still bearing clusters of the M41 bombs.

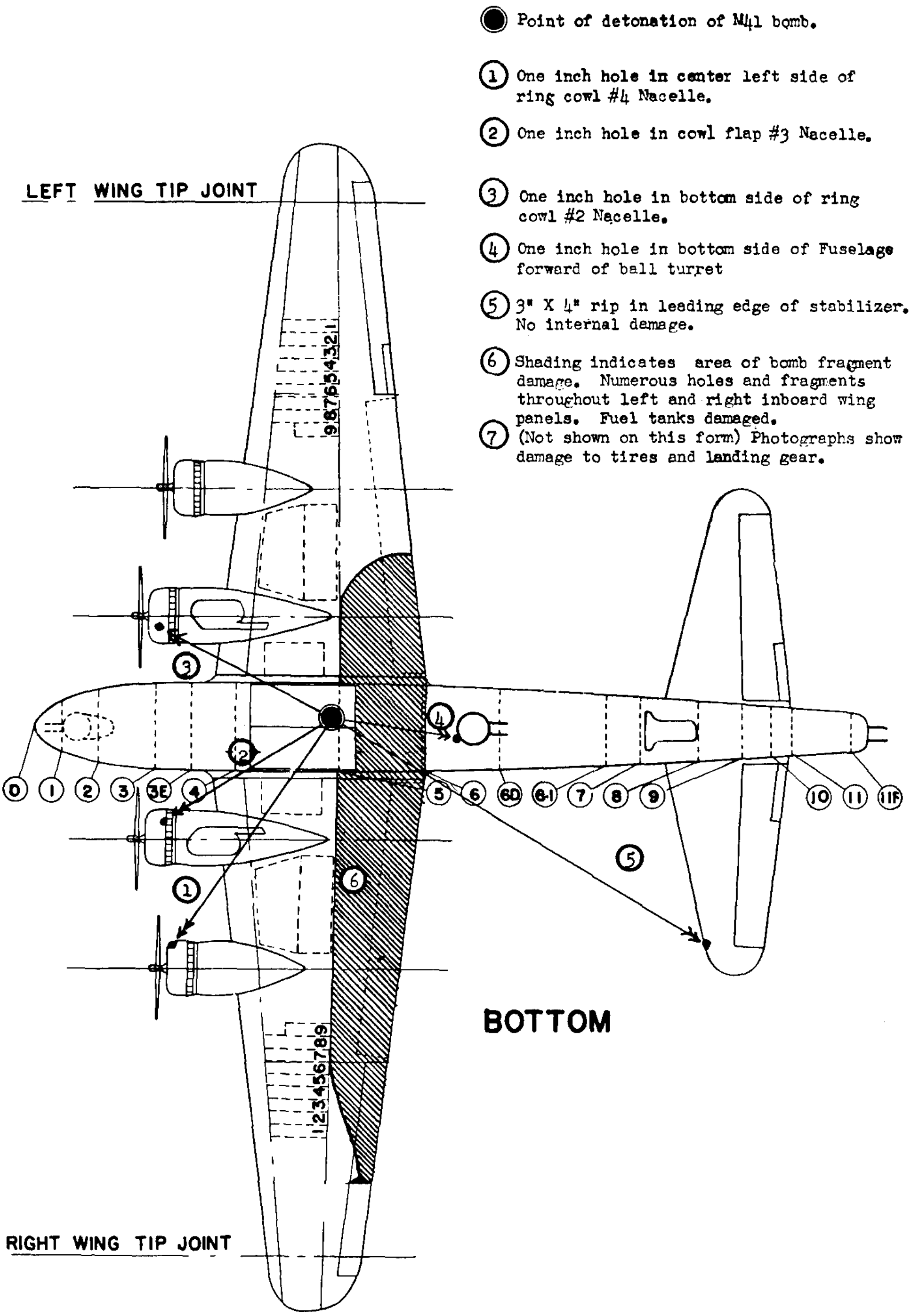


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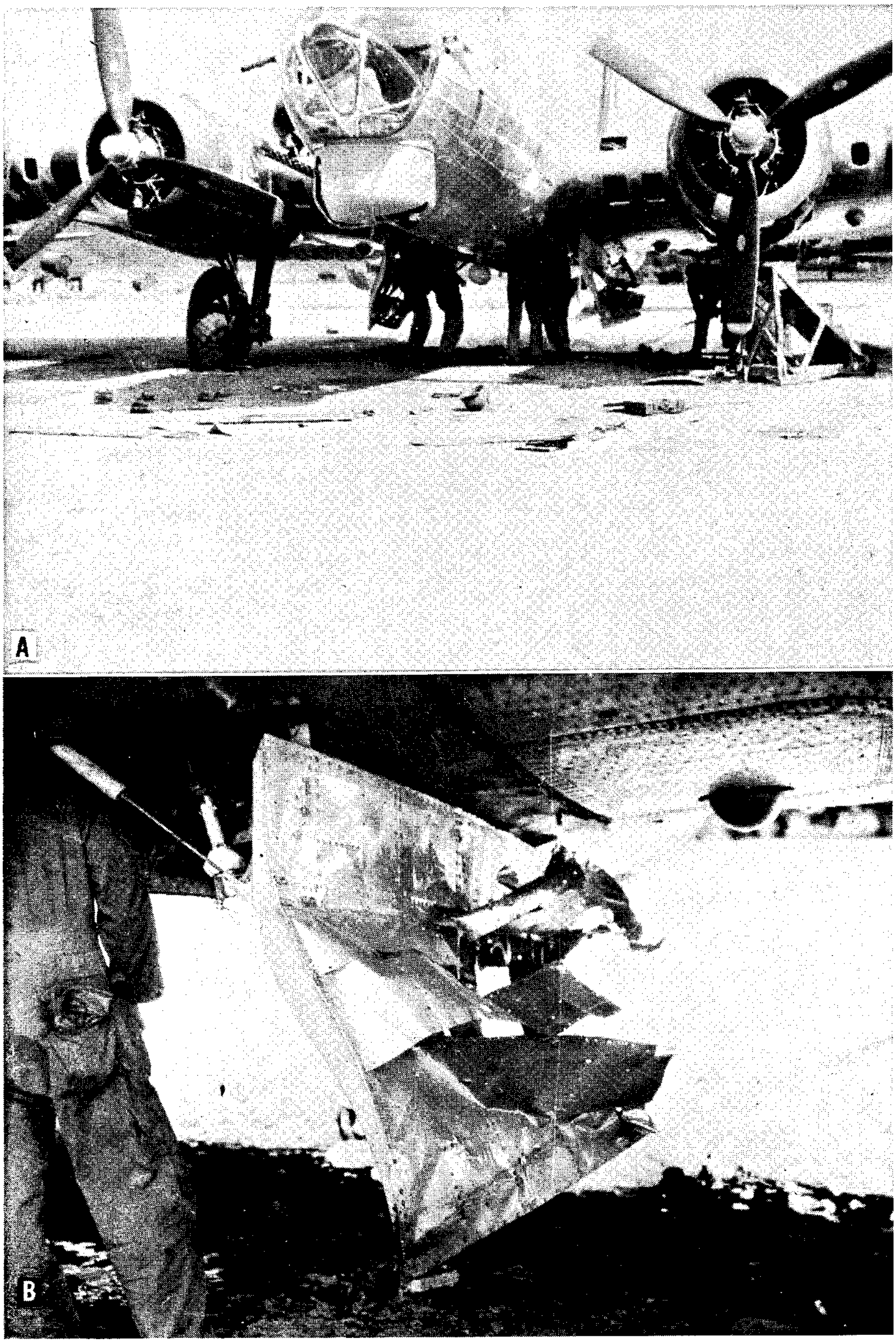
FIGURE 2.—Eighth Air Force ORS battle damage report on B-17-G No. 42-107210 aircraft.



U.S. Army photos

FIGURE 3.—Damaged aircraft. A. Aircraft B-17-G No. 42-107210 of 401st Bomber Squadron Group (H). B. Bomb fragment holes in wing.

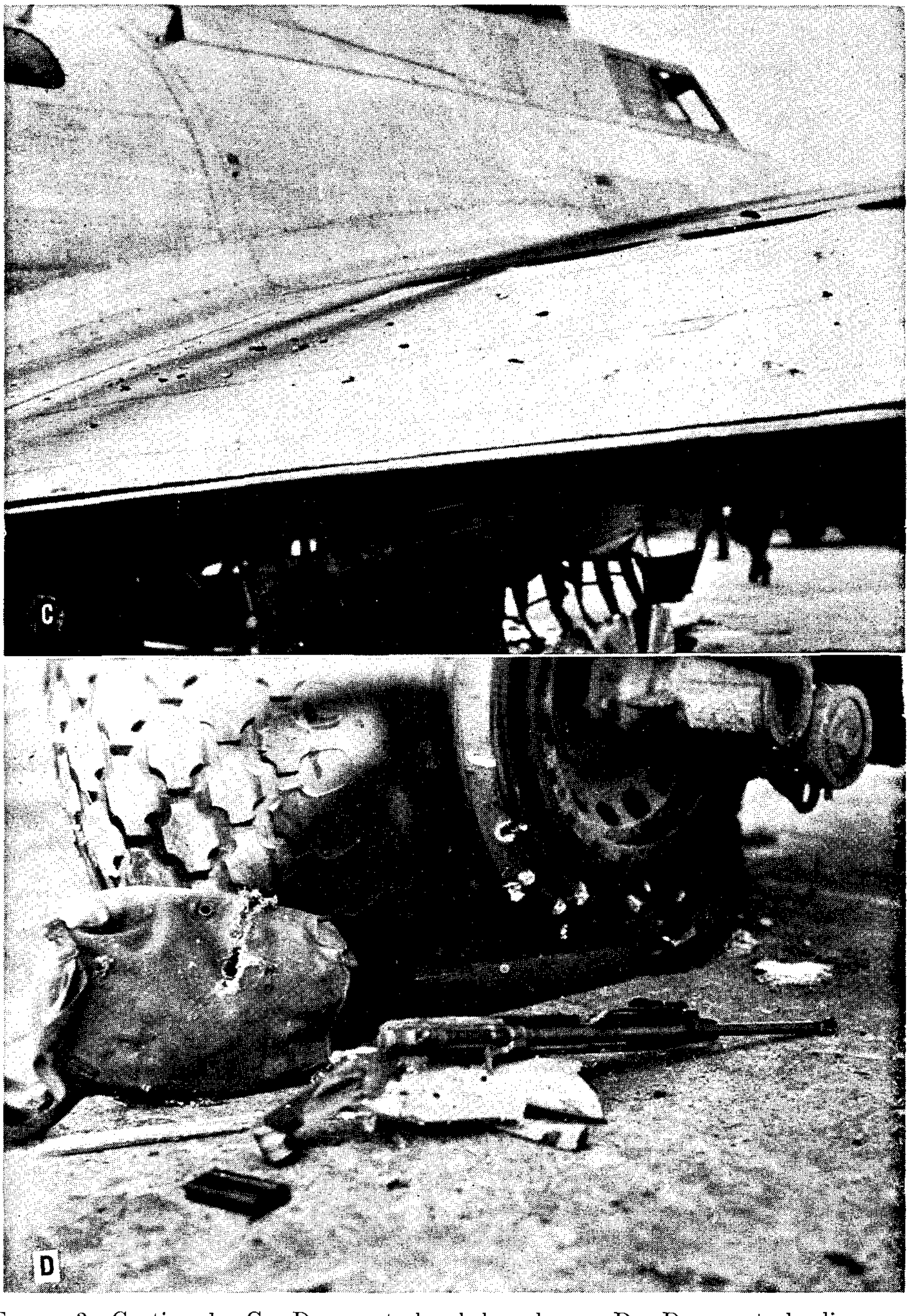


FIGURE 3—Continued. C. Damage to bomb bay doors. D. Damage to landing gear.

The B-17-G aircraft was located with the men grouped about it as shown in figure 1. Damage to the aircraft is shown in the Eighth Air Force ORS (Operational Research Section) battle damage report (fig. 2) and in figure 3. The category of damage is given as "E" which, as discussed in USSTAF (U.S. Strategic Air Forces) Regulations No. 80-6, 8 May 1944, refers to an aircraft damaged beyond economical repair, such as in crashlandings.

The pyramidal tent located 150 feet to the west of the burst received no hits by bomb fragments. The brick farm building (used as a workshop) diagonally 250 to 300 feet to the southwest was struck by at least 30 high-velocity fragments having a mass estimated to be from 5 to 10 gm. Pitting of the brick wall of the building to a depth of 1 inch or more served to indicate which fragmentation marks were the result of high-velocity fragments of the estimated weight. Most of the fragmentation marks were between 4 and 5 feet above ground level. Some of the marks seemed to be due to groups of smaller fragments. These marks were clustered about a larger and deeper mark, the clusters covering an area of 25 or 30 square inches. Two large fragment marks were found approximately 12 feet above ground level and several at a height of 6 to 7 feet. One fragment made a ¼-inch hole through a piece of iron pipe, the walls of which were an eighth of an inch, and came to rest buried in a wooden door. The pipe was part of some structural framework on the side of the brick farm building, and the point at which the building was struck was exactly 252 feet from the burst, 3 feet above the ground level.

The maximum depth of the bomb crater was 1¼ inches and was located, as shown in figure 1, in the concrete dispersal area. The fragmentation pattern was asymmetrical, indicating that the bomb struck the concrete nose first but with its axis deviating from the perpendicular. The pattern radiated from the crater toward the nose of the aircraft, through an arc of 220°. At the center of the arc, the pattern extended 6 feet. Maximum extensions of the pattern, amounting to 10 feet from the crater, occurred at 55° to the right and left of the center. Here the density of strikes was greatest. At the extremities of the arc, the pattern extended no more than 3 feet from the crater, with density of strikes very slight. From these facts, it would appear that the inclination of the bomb axis from the perpendicular was in the direction of the nose of the ship, where the majority of men at work were congregated. It would appear further that the normal horizontal spray of fragments occurred to the left and right of the aircraft as indicated by the fragmentation pattern and the level and distribution of fragmentation marks on the side wall of the brick farm building. The dispersal of fragments throughout the remaining 140° of the arc not represented in the concrete fragmentation pattern appears to have been upward and slightly backward through the wings of the aircraft. The total area of wing surface hit by bomb fragments was found, by planimeter measurement on a scale drawing of the aircraft, to be 27 square feet. In this surface area, there were 180 penetrations or an average of nearly 7 strikes per square foot at distances varying from 5 to 40 feet from the burst.

It is of interest to note from the configuration of the fragmentation pattern on the concrete that with the exception of casualty *A* all the rest of the casualties on the ground were produced by bomb fragments, the velocity of which may have been considerably reduced because of the retardation produced by the richochetting of the fragments against the concrete surface.

The technical supply hut south of the burst (fig. 1) received one through-and-through, hit on the convexity of the roof structures and three hits on its front about 3 feet above ground level. The bomb-carrying trailer present at the time of the accident was not available for inspection.

DESCRIPTION AND PERFORMANCE OF U.S. 20-POUND FRAGMENTATION BOMB

Construction

The M41 fragmentation bomb (fig. 4) has a charge-weight ratio of approximately 15 percent. Details of its construction are furnished by Prof. Marston Morse in his statement communicated to the Wound Ballistic Conference on 27 April 1944. The overall length of the bomb is 22.2 inches and its diameter about 4 inches. A long rod of square wire 0.44 x 0.44 inch is tightly wrapped about a light cylindrical casing 0.11 inch thick to form the main body of the bomb. The cylinder is filled with TNT or other explosives. The ends are sealed with steel plugs. The nose plug contains a cavity for an instantaneous fuse, and the tail plug has a threaded hole to take the tail fins.

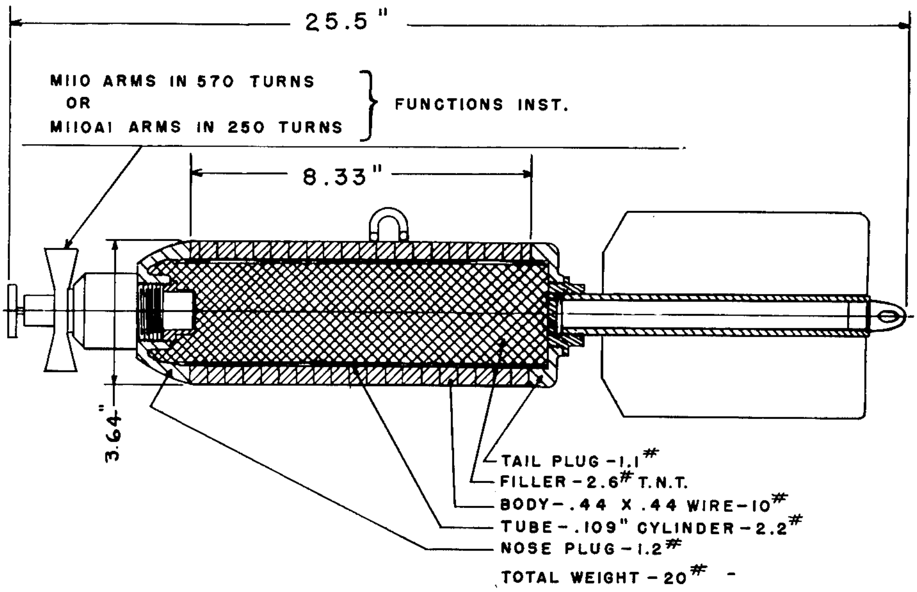


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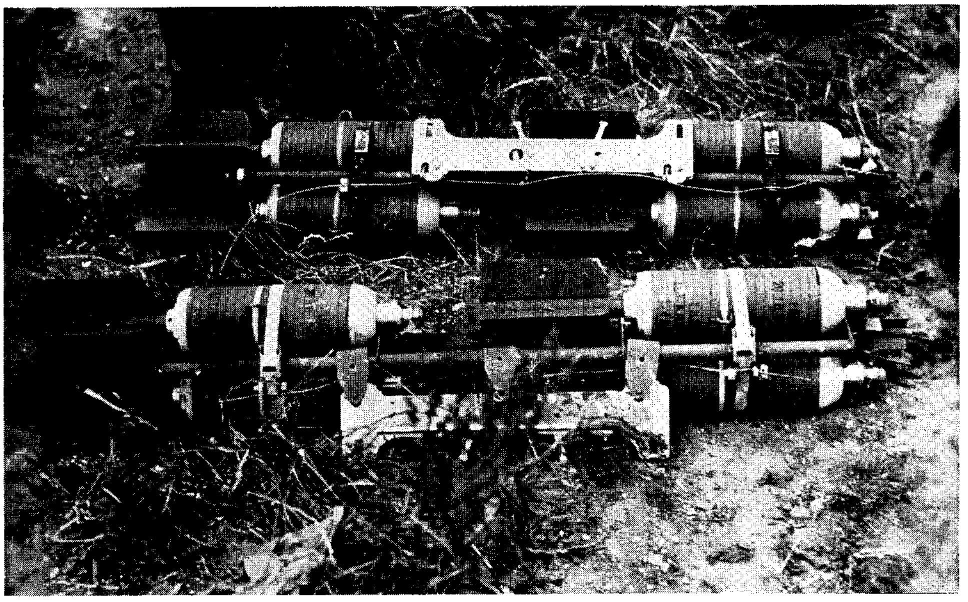
FIGURE 4.—U.S. 20-pound (M41) fragmentation bomb.

The bomb is normally clustered into the M1A1 cluster of six bombs (fig. 5). The following loads, prescribed in USSTAF Ordnance Memorandum No. 3–54, 16 March 1944, were carried by aircraft in use by the U.S. Air Forces:

Aircraft:	*Load* [1]
B–17	38–42
B–24	52
B–26	30
B–25	30

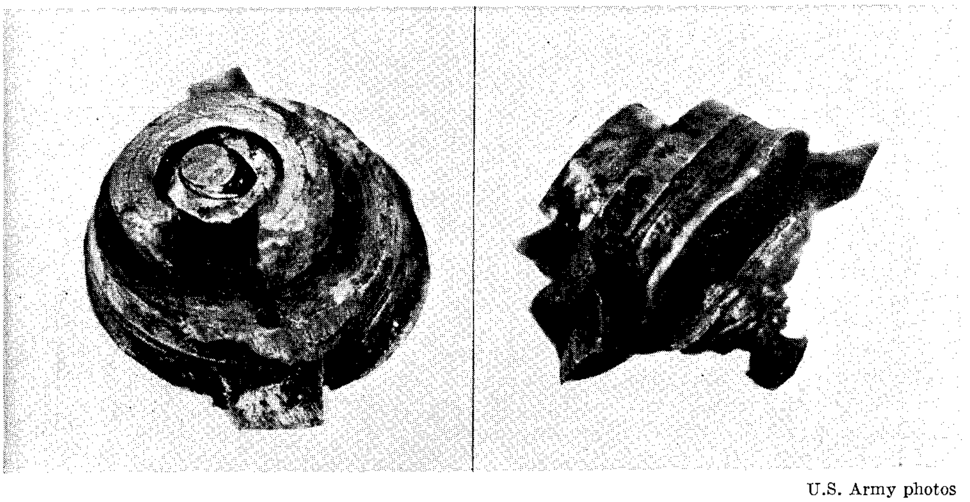
[1] In clusters of 6 bombs.

When an M41 bomb falls, 250 revolutions of the propellerlike blade, on the nose of the bomb, are required before the bomb is armed. This process permits the collarlike safety block located just ahead of the propeller to fall away, which in turn permits the striker head to be driven into the fuse upon impact. As stated in the official ordnance report (p. 827) and



U.S. Army photo

FIGURE 5.—M1A1 clusters of U.S. 20-pound (M41) fragmentation bombs.



U.S. Army photos

FIGURE 6.—Defective fuze of M41 fragmentation bomb, showing safety block in place.

as shown in figure 6, the safety block on the fuze of the bomb that exploded in the incident being reported was in place. Thus, the fuse functioned even though in a "safe" condition.

Fragmentation

The effect of wrapping the bomb cylinder with square wire is to produce a large number of fragments, each of which is a piece of rod 0.4 inch to 1 inch long (fig. 7). These fragments are much more effective per pound of metal than the usual long, narrow shell fragments.

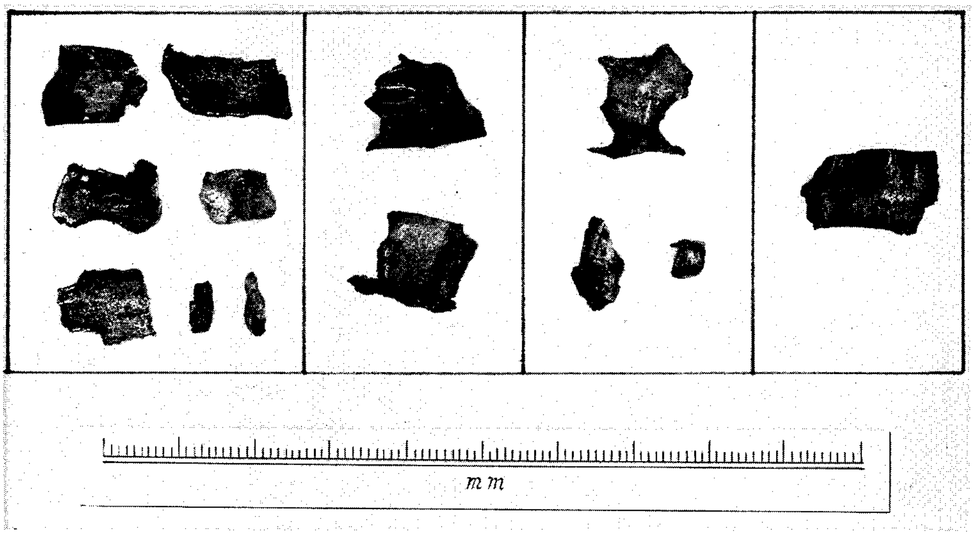


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FIGURE 7.—Primary missiles (U.S. M41 20-pound fragmentation bomb). Fragments found in wounds of aircrew personnel killed by the accidental explosion of the 20-pound fragmentation bomb.

In static and drop trials, the number of fragments recovered is approximately 1,000 for the TNT loading and is from 40 to 60 percent greater with ednatol or RDX Compound B loadings. For the TNT loading, 75 percent of the fragments exceed 2.25 gm., 50 percent exceed 4.0 gm., and 25 percent exceed 7.0 gm. in weight. In static and drop trials at the ordnance proving grounds at Millersford, England, quoted by Zuckerman, the number of fragments heavier than 1.3 gm. was 883. Fragments of less than 1.3 gm. were not counted. Zuckerman reports the actual recovery of 319 M41 bomb fragments, weighing more than 1.3 gm. each, from the roof of the Bocca di Falco Airfield Building, Palermo, Sicily, where a single M41 bomb had burst. The total weight of the fragments was 3.65 pounds, or about 25 percent of the potential fragmenting metal. Morse gives the figure of 1,274 as being the total number of fragments weighing more than 0.25 gm. each from one M41 bomb and, for comparison with the ordnance trials at Millersford, 884 fragments weighing more than 1.3 grams.

The initial velocity of M41 bomb fragments has been reported (Eighth Air Force Ordnance Memorandum No. 3–17, 18 Sept. 1943) to be as high as 4,000–5,000 f.p.s. However, the mean velocity of fragments heavier than 1.3 gm. measured at the Millersford trials was 2,890 f.p.s. over a distance of from 0 to 10 feet, and Morse gives the average velocity at 20 feet for all fragments exceeding 0.24 gm. in weight as 2,810 f.p.s. He states further that for ednatol loading the initial velocity is 3,000 f.p.s. and for an RDX Composition B loading, 3,280 f.p.s. The Sachs-Bidelman Memorandum Report No. 267 from the Aberdeen Proving Ground follows closely if it is not actually the same as Professor Morse's statement of velocities of M41 bomb fragments for the three different loadings given.

Effective Range

Because of its cylindrical construction, the zone of maximum fragment density for an M41 bomb is extremely narrow, being approximately not more than 3° above the equatorial

plane and then only when it bursts with its axis vertical. Slight deviations of the bomb from a vertical position materially affect its effectiveness. Ordnance Memorandum No. 3–17, 18 September 1943, gives as criteria for effectiveness against personnel a minimum of two fragment hits per individual. Since a man when standing erect is regarded as presenting an average target area of 4.2 square feet, this corresponds to a minimum fragment density of approximately 0.5 fragments per square foot for effectiveness. From this, it is estimated that the effective range for an M41 bomb exploding in the vertical position is 50 feet. Approximate calculations for angles of impact at 10° and 20° from the vertical give the following figures:

Angle of impact from the vertical position (degree)	*Radius of effective range (feet)*	
	Forward	*Rear*
0	50	50
10	33	8
20	13	3

The findings at the scene of the accident suggest that the angle of impact of the bomb was at least 45°. This assumption was made because it was found that a narrow zone of maximum density of fragmentation occurred against the undersurface of the wings of the damaged aircraft at a point slightly more above than to the rear of the point of impact.

The decrease in effective range forward, for a bomb striking at an angle, obviously does not hold for a bomb falling a short distance on a concrete surface.

STUDY OF CASUALTIES

An estimate of the risk of an individual to injury by bomb fragments may be made from the data in table 1. The factors to be taken into account are as follows:

1. Surface area of the body exposed, less area protected by parts of planes, objects, or other individuals.
2. Distance from burst.
3. Direction of fragment spray.

The mean projected area of the body and its parts, as recorded by Krohn working with Burns and Zuckerman,[2] enables one to estimate the approximate surface areas of individuals exposed to injury. From these data, table 2 was compiled. It is shown that, of the seven individuals within 30 feet of the burst and without any appreciable protection, six were killed or died as a result of wounds and the seventh injured so severely that he required more than 3 months' hospitalization and was permanently lost from the service. Two individuals, *M* and *N*, within 15 feet of the burst and with only their lower extremities exposed, were out of the line of spray of effective bomb fragments and sustained only slight injuries. Two others, *O* and *P*, within 30 feet of the burst were in the line of spray but because they were almost completely protected by other individuals were only slightly injured. The four remaining individuals, *I*, *J*, *K*, and *L*, who were further distant than 30 feet from the burst and who received injuries, required hospitalization for periods averaging longer than 5 weeks. Table 3 shows the casualty rates pertaining to the 24 men known to be present at the scene of the incident.

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[2] Burns, B. D., and Zuckerman, S.: The Wounding Power of Small Bomb and Shell Fragments. R. C. No. 350 of the Research and Experiments Department of the Ministry of Home Security.

TABLE 2.—*Observed hits by M41 bomb fragments sustained by casualties at various distances from burst*

["Area" refers to the approximate body surface area exposed to bomb fragments by each casualty in square feet]

Casualty	Distance (feet) from point of burst									
	0–15		15–30		30–45		150		>250	
	Hits	Area	Hits	Area	Hits	Area	Hits	Area	Hits	Area
A			19	4.2						
B			15	4.2						
C	44	4.2								
D	10	4.2								
E			8	4.2						
F			18	4.2						
G					2	1				
H			11	3.7						
I					12	4.2				
J					3	4.2				
K					1	1				
L							1	4.2		
M	10	1.65								
N	4	1.65								
O			3	1						
P			3	1						
S									1	4.2
Total	68	11.7	77	22.5	18	10.4	1	4.2	1	4.2
Observed hits per square foot surface area		5.8		3.4		1.7		0.2		0.2
Expected hits per individual when exposed area is 4.2 square feet		24		14		7		1		1

TABLE 3.—*Casualty rates of 24 men exposed to bomb fragments*

Distance from burst	Number of men exposed	Casualties (killed or wounded)	
		Number	Percent
Feet:			
0–15	5	5	100.0
15–30	7	7	100.0
30–45	5	4	83.0
>45	7	1	14.0

Figure 8 shows graphically the number of hits per square foot of body surface exposed at varying distances from the burst. These findings show a desirable distribution of fragments for antipersonnel effect and agree closely with the fragment density reported by Zuckerman in his communication from Sicily on the performance of the U.S. M41 bombs against grounded aircraft. It is of interest to note again that all of the casualties standing on the pavement toward the nose end of the aircraft, ahead of the burst, were presumably struck by fragments ricochetting on the concrete dispersal area.[3] Thus, in general, the

[3] At a later date, 28 September 1944, the writer recommended by letter, Special Incident Report, to Col. Elliott C. Cutler, MC, Chief Surgical Consultant, ETOUSA, that "* * * as a safety measure, some thought might be given by the Air Force to the loading and unloading of bombs * * * into and from aircraft on a specially prepared or selected surface."—J. C. B.

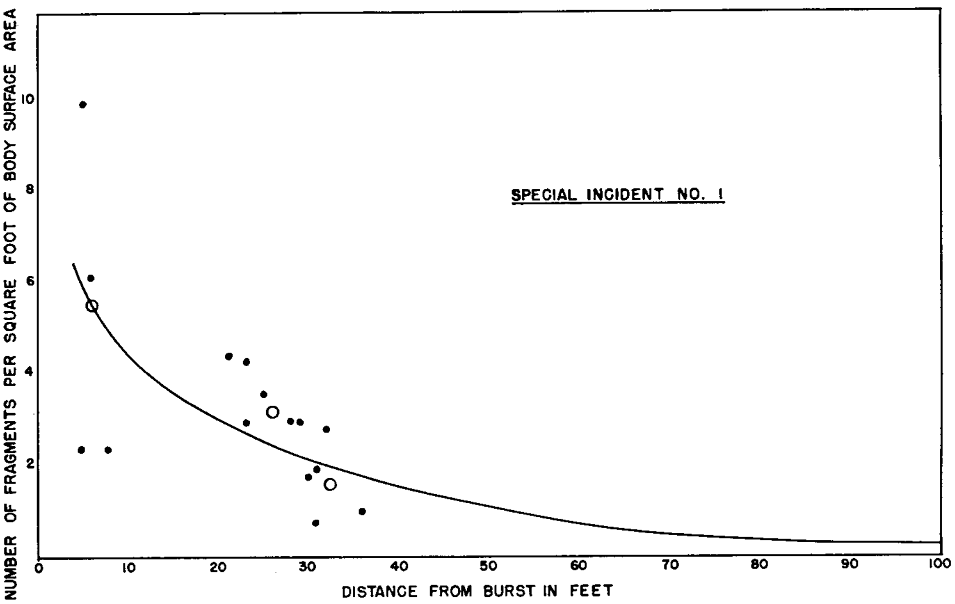

FIGURE 8.—Graphic presentation of number of hits per square foot of body surface exposed at varying distances from bomb burst.

distribution of ricochetted fragments against personnel in this incident closely approximated the distribution of fragments directly striking the wings of the aircraft damaged by the same burst. Further, the estimated fragment density at 50 feet in this incident was approximately three times as great as the estimate given in Ordnance Memorandum No. 3–17.

REGIONAL DISTRIBUTION OF WOUNDS

Table 4 shows the regional incidence of wounds in the 17 casualties. Only four individuals sustained single wounds, one of which was casualty *Q* who had only a slight tearing

TABLE 4.—*Distribution of 163 single and multiple wounds in 17 (11 wounded, 6 killed) casualties, by anatomic location*

Anatomic location	Single wound	Multiple wounds				Total wounds	
		2 regions involved	3 regions involved	4 regions involved	5 regions involved	Number	Percent
Head	2	1	3	1	5	12	7.4
Neck			1		3	4	2.4
Chest	1	1	6	10	29	47	28.8
Abdomen and scrotum			4	1	1	6	3.7
Upper limb	1	1	8	7	18	35	21.5
Lower limb		6	31	15	7	59	36.2
Total	4	9	53	34	63	163	100.0

of one eardrum. The greatest number of hits was 44, received by casualty *C* (killed). He was hit in five regions of the body including both upper and both lower limbs. This is a very conservative estimate of the number of hits since many of the wounds were so extensive that it was impossible to determine the number of bomb fragments that may have passed through the tissues.

The 28.8 percent incidence of thoracic wounds in this incident is greater than that reported in most casualty surveys of large samples and is obviously due to the inclusion of the killed with the wounded.

Table 5 shows the incidence and distribution of fractures. Four casualties sustained a total of 10 traumatic amputations of limbs or parts of limbs. These are included in the number of fractures. Of the 17 casualties, 13 sustained fractures and of these 10 had more than one.

TABLE 5.—*Distribution of 46 fractures (including amputations) in 17 casualties, by anatomic location*

Anatomic location	Number of casualties with fractures	Total number of fractures (including amputations)
Head	6	8
Chest	4	16
Abdomen	----------	----------
Upper limb	7	11
Lower limb	6	11

Casualty *B* (killed) presented the most extensive fracture of the skull, in addition to fractures of one upper and one lower limb. Besides comminution of the skull at the points of entrance and exit of a bomb fragment, all the bones of the skull and face, except the mandible, were disarticulated at their suture lines. The brain stem had been transected, and the entire substance of both cerebral hemispheres was macerated. The skull and brain appeared to have momentarily undergone an explosivelike expansion and cavitation. The missile stopped subcutaneously in the back of the neck after making its exit from the skull through the occipital bone.

Of the six dead, four had single or multiple penetrating wounds of the chest and one the penetrating wound of the skull described in the preceding paragraph. The sixth casualty, *D*, although he did not have a penetrating wound of the skull or other body cavities, did sustain traumatic amputations of his lower limbs in three places, multiple perforating wounds of his upper extremities, and superficial chest wounds. He presumably died almost instantly from shock and hemorrhage. His eardrums were intact.

The only evidence of damage by blast was the slight tearing of an eardrum in casualty *Q* who was within 10 feet of the burst but completely protected from a direct hit by the intervening inboard panel and clusters of bomb still in place. The eardrums of others, closer to the burst, were intact.

SIZE OF FRAGMENTS CAUSING WOUNDS

The sizes of fragments responsible for wounds were determined by weighing those recovered from the dead and estimating the weights of others from their X-ray silhouettes. In the case of the latter, the fragments were estimated in grams from their linear dimensions. A large series of X-rays of fragments of known weight were available as a standard. Table 6 summarizes the information obtained on this point and also gives the distances from the burst at which the casualties were struck.

TABLE 6.—*Size of fragments recovered from casualties struck at several distances from point of burst*

Category of casualty and distance (feet) from point of burst	Number of casualties	Fragment size (grams)					Total number of fragments
		0.001 to 0.05	0.05 to 0.25	0.25 to 1.0	1 to 5	>5	
Wounded:							
0–15	1	6	----------	2	----------	----------	8
15–30	3	2	7	6	1	----------	16
30–45	3	----------	6	9	1	----------	16
Total	7	8	13	17	2	----------	40
Killed:							
0–15	1	----------	1	2	----------	----------	3
15–30	4	----------	2	1	7	1	11
Total	5	----------	3	3	7	1	14

In all, there were 40 bomb fragments in 7 of the wounded that could be seen in X-ray films and 14 fragments recovered from 5 of the killed casualties. This represents a recovery of 90 percent of fragments causing wounds in the living but only 13.4 percent of fragments causing wounds in the dead.

The average weight of fragments causing wounds in the living casualties was 0.43 ± 0.65 gm., whereas the average weight of fragments recovered from the dead was 1.86 ± 1.82 gm. The difference in mean weight of fragments causing wounds in the killed and in the wounded in this incident involving a small number of people was found to be 1.43 ± 0.48 gm. ($t=2.98$, P less than 0.01). The difference in the mean weights is statistically significant. It may be assumed that the mean weight of fragments causing wounds in the dead is considerably greater than shown in the sample, since, by far, the majority of them caused through-and-through wounds and were not retained or recovered. On the other hand, the X-rays of fragments in the wounded that were available for study represent practically all of the fragments responsible for the wounds in the living. From the average fragment weight found in the X-rays of the living casualties, it may be said that M41 bomb fragments of less than 1 gm. in weight are relatively incapable of producing fatal injuries but are definitely incapacitating in their effect.

Bomb fragmentation trials in which the screens have failed to recover fragments weighing less than one twenty-fifth of an ounce lack ballistic data on fragments of such small size. However, the wounding power of small fragments has been discussed at great length by Burns and Zuckerman. Their conclusion that within the 100-foot radius of a bomb burst 50 percent of the wounding power of a 20-pound fragmentation bomb is due to fragments weighing less than one twenty-fifth of an ounce is well supported by the findings in this incident.

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APPENDIX H

Comparison of World War II Missile Casualty Data

Allan Palmer, M.D.

Detailed reports of missile casualty data obtained during World War II by special wound ballistics teams have already been presented in this volume. (See chapters IV, V, VI, VII, VIII, and IX.) A compilation of these data are presented in the statistical material in this appendix.[1] In addition, casualty data from previous wars have also been included as a matter of interest. However, no extensive comparisons have been made between casualties sustained during World War II and those sustained in previous wars because of the difference in weapons employed and of the difference in the medical and surgical eras during which the casualties were sustained.

The percentages in the tables that pertain to the regional distribution of wounds refer to the total number of wounds. In the case of regional frequency, only the frequency with which the various regions of the body are wounded is considered regardless of the number of wounds in each body region. The percentages in the tables which pertain to regional frequency of wounds refer to the number of casualties. From such tabulations, casualties who sustained wounds in more than one region of the body must be excluded or an additional entry made for them.

Table 1 shows the regional distribution of wounds due to all missiles in WIA (wounded-in-action) only, in three wars. The presentation of dissimilar samples is unavoidable since the statistical data have not been collected in a uniform manner. The outstanding difference in wound distribution in the various surveys is the relatively low incidence of chest and abdominal wounds in casualties sustained by the Eighth Air Force bomber crew members wearing body armor.[2]

There are only two surveys available on regional distribution of wounds in KIA (killed-in-action) casualties where the exact locations of all entry wounds have been recorded. Table 2 shows the regional distribution of the entry wounds due to all missiles in these two studies. Except for the moderately high incidence of chest hits (22.9 percent) in the Fifth U.S. Army dead, the location of hits approaches a random distribution; that is, the percentages of hits in the various regions are proportional to the mean projected areas of the various body regions. The protective effect of body armor in the trunk region, particularly the chest, is again demonstrable in the Eighth Air Force dead as shown by a wound incidence of 20.0 percent (chest and abdomen combined) as compared with 29.4 percent for the Fifth U.S. Army dead.

Table 3 shows the regional frequency of wounds due to all missiles in the killed in action of the Fifth U.S. Army and the Eighth Air Force surveys plus two additional surveys of U.S. battle deaths in the South Pacific Area. The regional frequency is shown by single and multiple regions wounded, and the numbers and the percentages refer to the number of

[1] Some variations will be noted in the statistical data presented in this section as compared to the data presented in the chapters referred to. This is due in part to the separation and reevaluation of the original survey findings in an attempt to compare the results from the varied sources upon similar terms. In addition, certain minor changes were made in the statistical data during the preparation of this volume. The statistical material pertaining to other than U.S. Army casualties was personally collected by the author during his Army service.—J. C. B.

[2] The presentation of data comparing ground troop and aircrew casualties might seem unfeasible, but they do indicate regional incidence of missile-inflicted wounds with a common implication for the development of personnel armor.—J. C. B.

TABLE 1.—*Percent regional distribution of wounds due to all missiles, from casualty samples of wounded in action only, in three wars*

War and survey	Casualty sample: Number of casualties	Casualty sample: Number of wounds	Body region: Head	Body region: Chest	Body region: Abdomen	Body region: Upper extremity	Body region: Lower extremity
American Civil War			9.1	11.7	6.0	36.6	36.6
World War I:							
United States			11.4	3.6	3.4	36.2	45.4
British			16.8	7.8	4.7	30.4	40.3
World War II:							
Canadians [1]		469	11.0	11.0	4.0	31.0	43.0
New Zealanders [2]	476	769	13.0	7.0	5.0	25.0	50.0
British [2]	112	202	14.0	6.0	3.0	28.0	49.0
German [2]	370	504	9.0	9.0	3.0	40.0	39.0
Allies [3]	183	352	10.0	11.0	7.0	33.0	39.0
United States:							
New Georgia-Burma	[4] 230		18.2	13.5	6.1	27.0	35.2
Bougainville	[4] 1,162		20.7	12.4	5.7	27.4	33.8
Cassino	100	133	20.0	11.0	7.0	22.0	40.0
Normandy	33,000		16.1	9.8	5.6	28.2	40.3
Eighth Air Force	[5] 1,007	1,298	19.8	4.9	2.2	29.4	43.7
U.S.S.R.			9.1	11.4	6.2	28.0	45.3

[1] At Dieppe Raid.
[2] In Tunisia.
[3] In Sicily.
[4] Casualties with multiple regions wounded are omitted from sample, and percentages are based upon number of casualties, not number of wounds.
[5] Heavy bomber aircrew personnel wearing body armor.

TABLE 2.—*Regional distribution of wounds due to all missiles in 1,000 Fifth U.S. Army and 164 Eighth Air Force KIA casualties only*

Body region	Fifth U.S. Army, Italy: Number of wounds	Fifth U.S. Army, Italy: Percent of wounds	Eighth Air Force, Europe: Number of wounds	Eighth Air Force, Europe: Percent of wounds
Head	680	10.5	105	23.3
Chest	1,484	22.9	58	12.9
Abdomen	425	6.5	32	7.1
Extremities:				
Upper	1,538	23.7	145	32.1
Lower	2,360	36.4	111	24.6
Total	6,487	100.0	451	100.0

casualties. Comparison of tables 2 and 3 shows the striking differences between the regional distribution of wounds and their regional frequency when dealing with samples of killed in action and died of wounds only. It has been observed that the dead are more frequently hit in more than one region of the body than is the case with the wounded. It is of interest to note that the regional frequency of hits in the Fifth U.S. Army casualties approaches more closely that for the Eighth Air Force dead than it does that for the dead that were studied in the Pacific theater. The effect of the wearing of body armor is again apparent in the air force study. The similarity in these two surveys is probably due to the fact that in both of

them the preponderance of missiles causing the casualties were high explosive shell fragments. The incidence of multiple regions hit was at least twice as great in both samples as it was in either of the samples of dead from the Pacific theater. The increased proportion of small arms or "aimed" fire characteristic of the warfare in the Pacific theater accounts for the high incidence of head and trunk wounds in these samples. This is an extreme departure from the randomness of hits as well as from the high incidence of wounds in more than one region of the body characteristic of casualties exposed to shell fragments.

TABLE 3.—*Regional frequency of wounds due to all missiles in four samples of battle deaths and KIA casualties*

Body region	New Georgia-Burma [1]		Bougainville [2]		Fifth U.S. Army, Italy		Eighth Air Force, Europe	
	Number of casualties	Percent of casualties	Number of casualties	Percent of casualties	Number of casualties	Percent of casualties	Number of casualties	Percent of casualties
Single region wounded:								
Head	32	31.7	144	36.4	171	17.4	50	30.5
Chest	32	31.7	87	22.0	138	14.0	16	9.8
Abdomen	11	10.9	48	12.2	30	3.0	3	1.8
Upper extremity	1	1.0	1	.3	25	2.5	----------	----------
Lower extremity	2	2.0	14	3.5	62	6.3	11	6.7
Multiple regions wounded	23	22.7	101	25.6	559	56.8	84	51.2
Total	101	100.0	395	100.0	985	100.0	164	100.0

[1] Includes both KIA casualties and casualties who died of wounds.
[2] Primarily KIA casualties only.

In the consideration of causes of death, a distinction has been made between the causes of death on the one hand and fatal wounds on the other. It was obvious that in many cases more than one wound could have been the cause of death. The following criteria were followed in order to determine the cause of death: [3]

1. Only the severest one of multiple fatal wounds was regarded as the cause of death in any one casualty.
2. When the severity of a head and a chest or an abdominal wound appeared to be the same, the cause of death was arbitrarily attributed to the head wound.
3. When the severity of a chest and an abdominal wound appeared to be the same, the cause of death was attributed to the chest wound.
4. Decapitations were regarded as causes of death due to wounds in the head and neck region in cases where the head was missing as well as in cases where a head wound was very extensive and associated with complete evulsion of the brain.
5. In the case of extensive mutilating wounds, the cause of death was attributed to a wound of the region of the body nearest the center of the area of mutilation.

Table 4 shows the causes of death in six studies of both military and civilian casualties due to all missiles according to the region of the body in which the primary fatal wound occurred regardless of the region first struck by the missile and regardless of the multiplicity of fatal wounds. Thus, the causes of death in these samples are not more numerous than the number of casualties.

[3] During the conduct of a survey, it is frequently necessary to adopt arbitrary criteria for the determination of the cause of death. However, autopsy studies have revealed the shortcomings of such a method. A thorough study of smaller group of casualties can be more informative than a superficial survey of a larger number. Therefore, casualty surveys should be conducted with adequate personnel to permit complete external examination of all wounds and an adequate autopsy study for the determination of the cause of death.—J. C. B.

TABLE 4.—*Percent distribution of cause of death in military and civilian casualties, by region in which the primary fatal wound occurred*

Body region	American Civil War (1,173 casualties)	British civilians in London [1]	New Georgia-Burma [2] (78 casualties)	Bougainville [2] (294 casualties)	Fifth U.S. Army, Italy (981 casualties)	Eighth Air Force, Italy (164 casualties)
Head	41.5	37.0	41.0	49.0	43.7	45.1
Chest	(3)	20.0	41.0	29.6	36.7	38.4
Abdomen	(3)	33.0	14.0	16.3	8.3	7.4
Extremities:						
Upper	2.6	4.0	2.0	.3	2.3	------------
Lower	4.5	6.0	2.0	4.8	9.0	9.1
Total	[4] 100.0	100.0	100.0	100.0	100.0	100.0

[1] Killed by bomb splinters during the "blitz" in 1941.
[2] Casualties with secondary fatal wounds omitted from sample.
[3] Data are not available for the individual body regions; for the combined regions, the figure is 51.4 percent.
[4] Includes 51.4 percent for wounds of the chest and the abdomen combined.

It may be seen in all of the casualty surveys that wounds of the head and neck region account for the greatest number of fatalities. The chest region is second in all samples except in that of British civilians in London during the "blitz" of 1941. It is possible that the suddenness of wounding by bomb splinters in unarmed and unprotected civilians, in contrast with the military, might account for a greater number of deaths due to abdominal wounds in civilians.

Whether or not there is complete random distribution of wounds in missile casualties can only be ascertained in complete samples of unselected casualties. The sample must include the slightly as well as the severely wounded and the killed. Table 5 shows the relative mean projected surfaces of the various body regions which may be regarded as the relative regional distribution of wounds expected in a sample of casualties exposed to random distribution of the missiles causing wounds. The variations from the expected wound distribution for five samples of casualty data are also shown in table 5. A lower than the expected number of wounds in the chest and the abdomen in the case of the air force casualties was due primarily to the wearing of body armor by aircrew personnel. The higher incidence of head and trunk wounds due to aimed fire or small arms is apparent in the casualties sustained by the ground forces in the Pacific theaters.

Just as in the case of wounded in action only casualty studies, there are only slight and insignificant differences in regional distribution and regional frequency of wounds in complete casualty samples. Table 6 shows the relative regional frequency of wounds due to all missiles in three of the complete casualty surveys previously discussed. The incidence of casualties wounded in more than one region of the body in the three complete casualty samples is fairly constant—ranging as it does from 14.9 to 18.6 percent. By excluding casualties wounded in multiple regions from the data in table 6, the greatest differences between the regional distribution and the regional frequency of wounds would be found in the Eighth Air Force survey. Although 40.4 percent of all wounds occurred in the lower extremities (table 5), if those wounded in multiple regions were excluded from the sample instead of being tabulated in table 6 as "multiple regions," the value of 38.3 percent in table 6 would become 45.0 percent, the difference between regional distribution and regional frequency then being 4.6 percent. Thus, it may be concluded that in an analysis of the regional distribution or frequency of wounds in complete casualty studies the exclusion of those casualties wounded in more than one region of the body does not materially alter the apparent incidence of wounds in the various body regions.

TABLE 5.—*Percent regional distribution of wounds due to all missiles, from six surveys of WIA and KIA casualties, by body region*

Body region	Body surface area [1]	Dieppe Raid [2]	North Africa [3]	New Georgia-Burma [4]	Bougainville [5]	Eighth Air Force Europe [6]
Head	12.0	16.0	21.5	20.1	26.4	21.1
Chest	16.0	13.0	17.3	20.6	15.9	6.4
Abdomen	11.0	10.0	9.2	10.4	7.8	3.3
Extremities:						
Upper	22.0	26.0	(7)	21.5	22.0	28.8
Lower	39.0	35.0	(7)	27.4	27.9	40.4
Total	100.0	100.0	[8] 100.0	100.0	100.0	100.0

[1] Percent expected hits.
[2] Based on 496 WIA and an estimated 124 KIA casualties.
[3] Based on a total of 3,919 casualties.
[4] Based on a total of 369 casualties, with 268 WIA casualties and 101 battle deaths, including killed in action and died of wounds.
[5] Based on a total of 1,546 casualties, with 1,162 WIA casualties and 294 battle deaths, including killed in action and died of wounds.
[6] Based on a total of 1,115 casualties, with 1,007 WIA and 108 KIA casualties.
[7] Data are not available for the individual body regions; for the combined extremities, the figure is 52.0 percent.
[8] Includes 52.0 percent for wounds of the upper and lower extremities combined.

It has been observed that shell fragments hit the body more at random than the aimed fire of bullets. While initial fragment velocity is often high, the striking velocity is commonly less than that of bullets at battle ranges, due to rapid air retardation. This effect is largely due to sectional density and form factor. It is this fact which makes body armor of value in protecting against fragment injury, while it would appear impractical to contemplate an armor which could materially prevent rifle bullets from causing wounds of the protected areas. Thus, it is proposed that the protective effect of body armor be evaluated on the basis of observed hits on personnel struck by shell fragments only. Ideally, a comparison of the anatomic location of hits on unselected samples of armored and unarmored troops would best reveal the effectiveness of protection. The exact anatomic locations of all hits by high explosive shell fragments on the surface of the body have been accurately recorded in one casualty survey comprised of both the wounded and the killed, that being the 961 Eighth

TABLE 6.—*Percent regional frequency of hits due to all missiles, from three surveys of WIA and KIA casualties, by body region*

Body region	Body sufrace area [1]	New Georgia-Burma	Bougainville	Eighth Air Force
Single region:				
Head	12.0	20.1	21.5	19.8
Chest	16.0	17.1	12.9	3.4
Abdomen	11.0	6.8	6.4	1.5
Upper extremities	22.0	17.1	17.9	22.1
Lower extremities	39.0	22.4	22.7	38.3
Multiple regions	----------	16.5	18.6	14.9
Total	100.0	100.0	100.0	100.0

[1] Percent expected hits.

Air Force flak casualties sustained during June, July, and August 1944 (ch. IX). All of these casualties may be regarded as being "armored." Although the exact incidence of those casualties who were not actually wearing body armor at the time they were wounded or killed is not known, it is known that at least 11 percent were unarmored.

A further evaluation of the protection afforded by body armor may be made from a study of the quantitative relationship (indices of vulnerability) between observed hits and expected hits based upon projected body surface areas. In a relationship of this sort, the nearest approach to random distribution of hits would be expected in a selected sample of casualties due to only fragments from high explosive shells, and the least evidence of randomness would be expected in a selected sample of casualties due only to bullets; that is, "aimed" fire. Since body armor is the subject under discussion, it is felt that selected samples of casualties due to high explosive shell fragments are best suited for this demonstration. Warfare in which bullets cause the majority of casualties would not be the type of warfare in which body armor would be of greatest value. A purely random distribution of hits on unprotected individuals would cause all the indices to be 1.00.

The regional frequency of hits due only to shell fragments in a sample of unarmored ground force troops may be compared with the regional frequency of hits sustained by the armored Eighth Air Force casualties. Table 7 shows the relative regional frequency of hits in the various body regions of the unarmored Bougainville casualties as compared with that of the armored Eighth Air Force casualties.

TABLE 7.—*Relative vulnerability of different body regions to shell fragments (multiple wounds excluded) from two surveys of WIA and KIA casualties*

Body region	Body surface area or hits expected (percent)	Bougainville [1]		Eighth Air Force [2]	
		Hits observed (percent)	Index [3]	Hits observed (percent)	Index [3]
Head	12.0	24.5	2.04	16.1	1.34
Chest	16.0	15.3	.96	4.6	.29
Abdomen	11.0	6.6	.60	1.8	.16
Extremities:					
Upper	22.0	21.9	1.00	29.0	1.32
Lower	39.0	31.7	.81	48.5	1.24
Total	100.0	100.0		100.0	

[1] Based on 707 casualties.
[2] Based on 818 casualties.
[3] $\text{Index}=\dfrac{\text{Percent of hits observed}}{\text{Percent of hits expected}}$

The action in which the Fifth U.S. Army in Italy participated and in which at times as many as 85 percent of the casualties were due to shell fragments was the sort of warfare which defensively would be ideally suited to the wearing of body armor by ground force troops. Casualty survey observations on the regional distribution of hits due only to shell fragments in this action, however, were restricted to a sample of KIA only casualties. Table 8 shows for comparison the regional distribution of hits due only to shell fragments and the indices of vulnerability in samples of 850 unarmored Fifth U.S. Army dead and 144 armored Eighth Air Force dead.

It is not fair to attempt to evaluate protection afforded by armor on the basis of observations confined to killed in action only. The chest and abdominal regions are still relatively vital regions of the body even when armored, and the fatalities resulting from fatal wounds in these regions were obviously due to the relatively higher velocity perforating flak fragments which struck these regions in armored aircrew personnel. These fragments approached and

actually may have had velocities which were comparable to the velocities of bullets. A point which may be observed, however, in the two surveys with reference to protection is the difference in the distribution of wounds. The sample of air force dead may be regarded generally as having worn helmets as well as body armor as opposed to the sample of ground force dead which may be regarded generally as having worn helmets but not body armor. Therefore, with greater vital body area coverage by body armor as compared to area of coverage by helmet only, the incidence of head wounds due to shell fragments in air force dead was more than twice that in ground force dead. The low incidence of head wounds due to high explosive shell fragments in the dead of the Fifth U.S. Army was the only instance in all of both the complete and KIA-only casualty surveys studied where the incidence of wounds was less than the projected surface area of that region; that is, less than the expected wound incidence. Figures 1 and 2 show the anatomic location of the hits given in table 8 for the ground force and air force casualties, respectively.

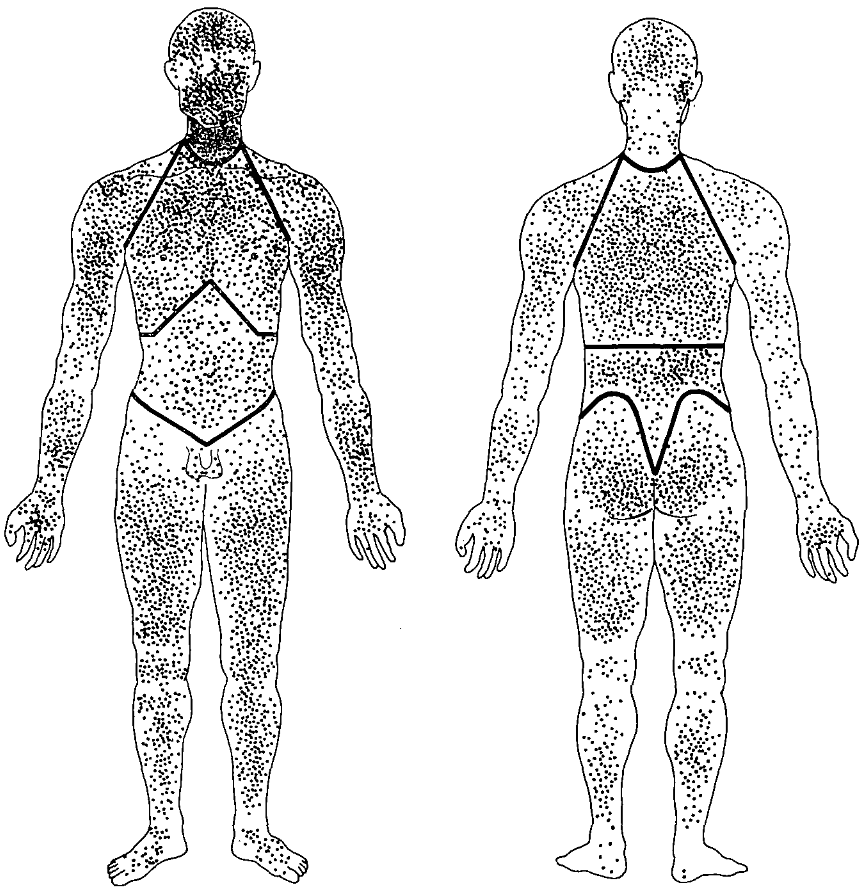

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FIGURE 1.—Anatomic location of 6,003 hits on 850 KIA due to shell fragments, Fifth U.S. Army, Italy.

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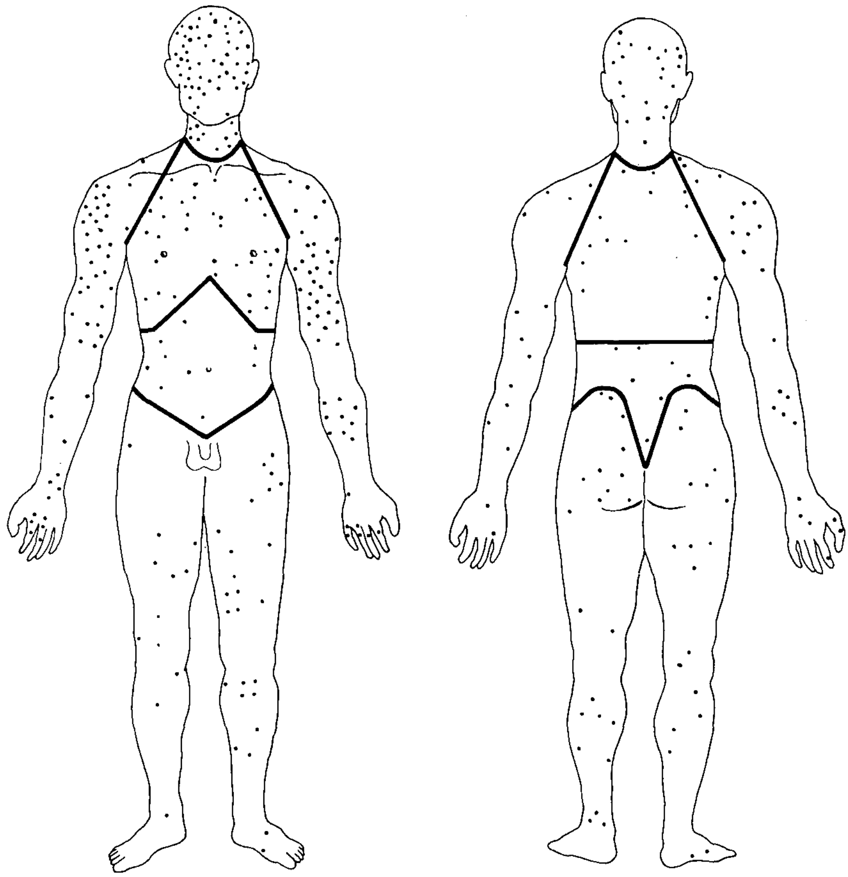

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FIGURE 2.—Anatomic location of 373 hits on 144 KIA due to flak fragments, Eighth Air Force, Europe.

TABLE 8.—*Percent regional distribution of wounds and relative vulnerability of body regions to shell fragments, from two casualty surveys of KIA casualties only*

Body region	Body surface area or hits expected	Fifth U.S. Army [1]		Eighth Air Force [2]	
		Hits observed	Index [3]	Hits observed	Index [3]
Head	12.0	10.4	0.87	24.7	2.06
Chest	16.0	22.4	1.40	11.5	.72
Abdomen	11.0	6.6	.60	5.9	.54
Extremities:					
Upper	22.0	23.5	1.07	36.5	1.66
Lower	39.0	37.1	.95	21.4	.55
Total	100.0	100.0		100.0	

[1] 850 casualties with 6,003 wounds.

[2] 144 casualties with 373 wounds.

[3] $\text{Index}=\dfrac{\text{Percent of hits observed}}{\text{Percent of hits expected}}$

APPENDIX I

Medical Program for the Study of Wounds and Wounding

Major James C. Beyer, MC

A comprehensive medical program in the continuing study of wounds and wounding would include the following:

Functions:

1. To insure a coordinated and standardized reporting of battle casualty statistics.
2. To consolidate and unify operations in order to furnish a complete and continual coverage of any hostility.
3. To simplify the establishment of a research unit in an overseas theater.
4. To serve as a source of material for all interested developmental and planning agencies in the Medical Corps, the Quartermaster Corps, the Army Field Forces, and the Ordnance Corps.
5. To provide a consultation group for all medical problems pertaining to the use and development of body armor and weapons.

Types of work:

1. The scope of the work should include all types of battle casualties and certain related nonbattle casualties.
2. Statistical survey as to:
   a. Number of wounds per casualty.
   b. Regional incidence of all wounds.
   c. Regional incidence of lethal wounds.
   d. Type of wound.
   e. Causative agents—type, weight, velocity.
3. Wound ballistics studies:
   a. Size and shape of wounds.
   b. Severity of wounds.
   c. Photographs of wounds.
   d. X-rays.
   e. Missile passageway.
   f. Recovery of missiles.
4. Pathology:
   a. Studies directly related to wound ballistics.
   b. General studies related to effects of stress and combat.
   c. Companion studies not related to wound ballistics.
5. Studies of survival time and cause of death in DOW's and KIA's.
6. Body armor studies:
   a. Effectiveness of body armor.
   b. Use and development of protective equipment.
   c. Comparison studies of allied troops not wearing body armor.
   d. Possible use of body armor in atomic-type warfare.
7. Wounding as related to training, tactics, terrain, type of combat, and so forth.
8. Long-term followup of WIA personnel as to hospital stay, type of recovery, sequelae, and so forth.
9. Studies of hostile WIA and KIA.
10. During peacetime, the members could be engaged in:
    a. Completion of studies and reports.
    b. Laboratory experimentation and field tests.

c. Investigation of accidents involving U.S. weapons.

d. Training and consultation.

A program of this caliber and magnitude would require that at least some of the participating medical officers should be qualified in pathology and have some training at the Ordnance School and the Ballistics Research Laboratory, the Medical Laboratories of the Army Chemical Center, and Army Field Forces schools. A basic knowledge of the essential statistical methods would also be of great value.

With the development and greater usage of the nuclear-type weapons on the battlefield, battle casualty survey units would possess the appropriate organization to continue the studies on the effects of the conventional weapons and expand to cover the combined effects of both agents. In order to facilitate the prompt utilization of such a unit in the event of new hostilities, it would appear that some consideration should be given at the present time (1961) to the planning and conception of the program. Hurriedly placed missions in the field will fail to realize a comprehensive harvest of all the available material.

The flow of casualties from the main line of resistance into medical installations provides several ideal locations for the conduct of various phases of a comprehensive battle casualty survey. In order to gain information regarding the casualty-producing effectiveness of U.S. weapons and to furnish essential data to the experimental wound ballistician who is collaborating with the ordnance design engineer, a temporary survey of the enemy KIA casualties should be made. All wound tracks should be charted, measured, and dissected with an attempt made to recover all retained missiles. Enemy WIA casualties can also be studied at prisoner-of-war sites.

Permanent teams should be available at mobile army surgical hospitals for the twofold study of WIA and DOW casualties. In addition, any KIA casualties who reach such an installation can also be included. A medical officer is required to direct the program, and he can be supplemented by Medical Service Corps officers and enlisted men with adequate equipment and personnel within the survey team proper for complete photographic and X-ray coverage of all casualties. Concurrent with the studies at the mobile army surgical hospitals, personnel must be available to conduct interviews and to collect data regarding the immediate circumstances surrounding the time and the place of wounding of each casualty.

The study of the WIA casualties should be a continuing process extending to evacuation hospitals and on to the Zone of Interior or to the point of final discharge of the casualty. Therefore, the disposition of each surviving wounded casualty is determined and copies of the autopsy examinations and abstracts of the clinical records for each DOW casualty are forwarded to a central agency.

Study of the KIA casualties is contingent upon the type and place of burial utilized by the Quartermaster Graves Registration Service. This again is dependent upon the scope and location of the hostilities. When local cemeteries are established in the theater, a survey team should be attached to each one. Here again, the survey team should be able to function as an integral but independent unit with minimal dependency upon the local command for personnel, equipment, and supplies. The survey team members who are conducting interviews and collecting information concerning the circumstances of wounding of the WIA casualties can gather similar data for the KIA casualties. This information is of prime concern in determining the effectiveness of any items of personnel armor, such as the helmet and forms of body armor.

All of these activities, with definite basic plans drawn up concerning the conduct and scope of each phase, should be considered before the onset of any hostilities. The methodology governing the gathering of data should be investigated, and an acceptable format should be established. In that way, many of the shortcomings of the statistical data presented in this volume will be avoided and all interested agencies will be willing to accept any of the findings. Many of the variations in the tables of the preceding chapters have a valid and logical explanation, but there are numerous other disparities which could have been eliminated if uniform data collecting procedures had been established.

Therefore, to achieve any degree of success in such a program, one agency should be responsible for developmental planning, for training key personnel, and for providing a single repository for storage and dissemination of the material. In addition, personnel and loan material would be available for indoctrinating newly appointed medical personnel and for the continuing education of all interested individuals. A component of the Office of the Surgeon General would be most qualified to direct the program.

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